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Civilian Defense and Public Water Supply

By U. S. Grant 3rd

I AM rather surprised to find myself here before this Association. Professionally, I have not had very much to do with water works or water supply, outside of several cases of water supply problems in the field on various minor expeditions, and I don't think you want to hear about them. Perhaps the most useful thing I can do is to try to explain how civilian defense ties in with the entire civilian economy and with your particular professional problems.

The duty and responsibility for protecting their own property, their own lives, their own homes, rests in these United States, upon the communities themselves, and the states. Therefore, we do not have a large government department that is managing civilian defense as a matter of direct administration.

Recently a colonel of the Brazilian Army who is in charge of civilian defense called on us, and in going over our relative organizations, I was very much interested to hear him say that actual directives are given and can be enforced, by the federal government in Brazil in regard to civilian defense. He added, however, that even so, it is sometimes very hard to get the municipalities to do anything about it; so perhaps that authority is not necessary, and perhaps our set-up, discouraging as it may seem at times when we find communities that are just not interested, works about as well.

In fact, when I joined the office some months ago, what struck me most forcibly was the patriotic interest and patriotic services that were being rendered by the people of the United States in civilian defense. When you consider that we have a volunteer army of something like 11,000,000 volunteers in the Citizens Defense Corps and in the war services—the largest volunteer army that has ever been raised in the history of the world—I think you will appreciate that the people of the United States have really taken this subject seriously and that they are in the emer-

Address given on June 16, 1943, at the Cleveland Conference, by U. S. Grant, 3rd, Major-General, Chief, Protection Branch, Office of Civilian Defense, Washington, D.C.

gency to do their share. It is the best answer, possibly, to Hitler's claim that he had no fears about the United States because we were so divided and such a melange of different races that we could never get unity of action.

However, we must remember constantly that the importance of actually doing what is necessary for civilian defense rests upon the municipalities and the states, and that the federal office merely guides the community effort and the state effort.

Our office is largely devoted to investigating various problems and looking over all the information that is obtainable from abroad. All the material we can get as to experience in civilian defense abroad we digest, and find ways of adjusting to our particular set-up the organization that will be best for each community; we tell the community what that organization is and how it should function. In other words, ours is an entirely advisory office of the government.

Duties of the Protection Branch

Civilian defense is divided mainly into two major branches, each of them headed by an assistant director; one, the protection branch; the other, the war services branch. The protection branch is particularly concerned with all the programs that are necessary in order to meet and counteract the enemy action. The war services branch is interested in obtaining the volunteers; that is, recruiting; in setting up the defense councils and organizing them and in carrying out the other programs—the more purely economic and welfare problems that have become necessary because of war conditions.

The protection branch, first of all, is naturally concerned with protection against air raids. With the success we have had in the Pacific and also in Europe and Africa, there is naturally a tendency for us to think that that danger is over. I, personally, feel very strongly that we must not permit such a sense of security to creep in on us. The reason that we have had to make such a terrible effort in this war; the reason it has cost us so much and the reason it has taken us over a year—in reality two years—to get into the condition to do something offensively against the enemy, is because for some 20 years before this war there was an insistence in this country that there was not going to be another war, and we were not in danger and we could keep out of it. A few of us in the regular service were fanatical enough to believe there was going to be another war and that we ought to try to keep up-to-date what little armed force the Congress permitted us and to develop new types of warfare and develop new types of equipment.

But the people who thought there was not going to be a war were wrong. If we consider that the Japanese government has assured its people that they would never be bombed, and yet Tokyo was bombed; if we consider that Goering assured the German people no enemy bomb would ever be allowed to fall on a German city, and they are falling on German cities every day, and he was wrong—perhaps it would be wise for us to believe that those who assure you now that there will not be an attack may also be wrong.

Consider the circumstances surrounding the Tokyo raid. At that time everything seemed to be going against us. The Pacific was entirely in the control of Japanese naval power, and we were not able yet to do anything on the Atlantic or on the other side of the Atlantic. Our morale was at its

lowest and people were beginning to be discouraged; the armed forces even were discouraged. If you remember at that time when we heard that Tokyo had been raided, we all got a thrill; we were all very much enthused. Our morale went up. We felt that America really could do something. Are not the enemy leaders going to feel as we did when things begin to look really desperate for them? When they realize that perhaps the submarine campaign is failing to destroy the goods produced by our industry, that will be the time they will feel it is worth their while to take the risk. They may feel it is worth while to sacrifice a considerable amount of air power and some naval power in order to hit us at home. Certainly there must be no Pearl Harbor in the United States.

So we insist that it is necessary that the protection organization be maintained at the highest standard of efficiency possible and that it be trained and equipped as far as possible.

Federal Aid

Now one of the things the federal government has been able to do, in order to help out, is to buy certain essential equipment which the states and the cities could not very well buy for themselves and lend it to them for their protection, or better protection, in case they are attacked by an air raid. That equipment has for the last three months been finding its way to the various communities to which it is allotted. The allotments are made to the communities which are believed to be in the greatest danger of air attacks.

Presuming that an enemy is not going to attack the country broadcast, but is going to pick out the places where he thinks he can do the most damage, we have tried to help those communities which had plants, or population, or activities, or what not, that would be inviting to the enemy as targets. We have tried to equip them especially, but we have not been able with the small means at our disposal to protect the whole country. It is a tremendous country and equal protection could not be given to everybody.

There are other things, however, besides an air attack that are a part of the war effort, and must be considered and must be taken care of. For instance, every bad fire that takes place today is a real loss to the war effort. I remember when I was in San Francisco on February 28th last, the Abers Flour Mill burned down in Oakland. The Abers Flour Mill was not a vital plant to the entire country. There are other flour mills, other supplies of wheat and flour. However, when you consider that in that one fire there was destroyed the wheat and flour that would have supplied the flour ration for 500,000 men for one year, you can realize that the loss of that amount of wheat and flour is really a serious loss to the war effort; and moreover, that mill cannot be replaced immediately. It is not like in time of peace, because the machinery, the materials, the labor are so hard to get now-a-days that probably it is a total loss for the duration of the war.

The other day we ran across a warehouse that had been condemned because it was considered unsafe structurally. In it we found stored something like 150,000 automobile tires. It was not protected in any way, and it seemed that while the loss of 150,000 automobile tires would not stop our expeditions that may be forming right now in Europe, 150,000 tires lost in this country today will affect all of us to some extent by making tires that

much scarcer. Therefore, there is the protection of such supplies and such facilities that is necessary to assist the war effort.

Facilities Security Division

I might explain that in approaching that problem there are evidently certain plants, certain production facilities, certain communication and other similar facilities which are so vitally important to the war effort, to the immediate effort of the armed forces, to the immediate equipment of the armed forces, that responsibility for their care and protection has been taken over directly by the Army and Navy. They are listed on what is known as the Army Master Responsibility List, and the Army is directly responsible for their protection in every way; but like these other cases that I have spoken of, there are a great many plants and facilities that are not directly vital to the military effort but are essential to the country in its general war effort. At various times the President had assigned to different government agencies already existing, already in touch with the facilities or their field of production, the responsibility for seeing that these are taken care of and secure.

For instance, the Bureau of Mines was assigned a responsibility for the security of the mines throughout the country, especially the most essential ones. The Public Health Service was naturally assigned responsibility for the water supply plants throughout the country. The Federal Communications Commission was naturally given responsibility for the communications that come within the purview of its peacetime duties.

In all, there are some nine agencies that have special programs of security of that sort; and in addition, the FBI has the general responsibility for discovering and taking necessary action in regard to subversive activities. However, all of these agencies are limited as to personnel and as to facilities and there is a limitation to what they can do. Naturally, they all have a somewhat different approach to the subject. Last May, just about a year ago, it was decided that their efforts should be coordinated and the various security programs should be standardized. In order to do that, by an executive order the President charged the Office of Civilian Defense with what he called the Facilities Security Program.

So we have in the Protection Branch besides the Protection Division and besides the Medical Division (with the work of which you are probably very well acquainted and which provides the emergency medical service throughout the different communities of the country), a Facilities Security Division which is trying to operated this security program. We are in very close touch with the Provost Marshal General's office and in our nine regions we are in very close touch with the military service commands, because the Facilities Security Program necessarily is supplemental to, and has to gear in with, the Army interior security program.

One of our main objects is to avoid duplication. One of our main efforts is to try to find ways in which the number of visits of government inspectors to different plants and different facilities will be reduced and the management disturbed that much less. Otherwise, the Facilities Security program contemplates that the particular participating agency, that is, the particular government agency in charge of that program, will communicate direct

with the facilities, will look into what they are doing for their own security, and will recommend to them from their technical knowledge and their overall experience the best measures to take for their proper security. Each one of these programs is made up in conference of the participating agency with our office and is planned to conform to the corresponding security measures that are being taken by the Army. We try to make up a program which standardizes what the participating agency will ask or recommend to the particular facility to do in each case, to establish standards that should be met and to establish a list of essential facility priorities according to which the effort will be emphasized. If the particular facility, or plant, does not come on that essential facility list, we will limit ourselves entirely to answering questions that the management may ask, putting at their disposal information as to measures they can take in order to protect themselves further.

Organization for Water Supply Protection

I don't know whether I have made this clear; but coming down directly to the program in regard to domestic water supply, this is the primary responsibility of the Public Health Service.

The Public Health Service has not the enormous personnel that it might need in order to carry out the program. Therefore, in considering the domestic water supply of each individual community we will have to have recourse to and undoubtedly have the help of the state health officer and whatever other state officer is best acquainted with the water supply problems in that state; and also the help of the municipal authorities who are interested equally and who have the responsibility for instituting proper protective measures and enforcing them. We will expect to work through them and count on their help, and on the contribution that will be made by the Public Health Service. Information from our office will be rather limited to suggestions that will be helpful to them in deciding what they really should do and what they can do.

We have one other source of very competent personnel and that is in our Medical Division. In our Emergency Medical Service we now have some sanitary engineers in each region who are able to give very valuable technical advice and presumably will know what the protective measures are which have been decided to be most essential and how they will operate. In this particular program we don't have to go out and hire many thousands of inspectors who, if we did hire them, probably wouldn't know very much about water supply problems. We feel we can depend upon the municipal and state officials who know most about it, with the help of the Public Health Service and the help of our sanitary engineers, to do what is necessary and what is essential. Evidently, the security of domestic water supply is one of the most important, if not the most important facility to the civilian population and to the war industries. I think we have all come to realize this is just as important to the fighting forces, to the field forces, as the number of men the field forces have; because without those industries they would be unarmed and lacking in ammunition and supplies.

The importance of the security of the domestic water supply, you all know. I realize I am not telling you anything new, but I just want to

sketch in a very few words, the subdivision of the program as we see it which is divided into two main characteristics, or two main fields of endeavor. One is the physical or construction part of security; in other words, the protection of the water supply and its physical elements against possible damage by air attack, or damage by sabotage, or even by accident. It doesn't make any difference to the people of a city whether the water supply is injured by direct enemy action, by sabotage, or by accident. If the water supply goes out, the population suffers. The physical problem, or element, of the security program, therefore, considers possible ways of bypassing breaks that may occur, possible ways of furnishing alternative breakdown pumping power where pumping is necessary. Since fire is about 80 per cent of the damage done by an air raid and is today the major damage that is being done to our war industries and to our civilian economy throughout the country, the physical part of the problem includes estimates as to the adequacy of the water supply for fighting such great fires as would be a national disaster and amount to a battle won by the enemy.

Duplicate Supply Facilities

Mr. Horatio Bond of the NFPA staff has recently been in England. He has come back with a special message on the desirability and necessity of providing local water supply for fire fighting. In other words, a system of water supply where possible and where the situation is really critical, which will store a certain amount of water either in tanks or in surface reservoirs, from which it can be pumped by fire engines, which will be adequate to take care of a disastrous fire. The tanks or reservoirs can be kept filled from the normal water system, but it will not be wise to depend on the normal water system for such fire fighting unless it is very ample for the entire load of fire fighting, possible losses due to breaks and physical destruction, and the needs of the population.

I think the idea in some cases is certainly worth consideration. You all know best the extent to which an alternative system of water supply may be needed in your communities and what the measures are by which it can be improvised or taken care of. Manifestly the more important the city, the larger the city, the larger its industries, the more important its place in the general economy of the nation, the more interested we are in having proper security measures taken.

Water Quality Protection

On the other side of the picture, is the actual character of the water itself, which is tremendously important in time of war, in a time like this when certain communities are terrifically overcrowded—the nation's capital itself has increased 42 per cent in population in two years. A place like Norfolk, Virginia, offers a very serious special problem, or a place like Contra Costa County, California, where the population has increased from something like 30,000 to nearly 200,000. Those places all offer very serious and very particular water supply problems, and manifestly call for a strain on the water supply systems which it is very difficult for them to meet. If you superimpose on that strain—that overload which you may have been able to meet by various devices—the possible fire load of an emergency large fire, you will come to the point where the water available, even with all the ingenuity

in the world, may not be enough to see the community through.

That is the problem that I would like to bring to your attention today.

The other side of the problem is that in these communities that I have spoken of, the question of maintaining the purity of the water supply has become more difficult. Any loss in that purity will mean a much larger effect in the way of an epidemic or of general sickness in the population depending on that water supply. Moreover, since the population is either part of the armed forces that are stationed near the city or living in the city, or is part of the war industry working personnel, the harm to the war effort due to such an epidemic or due to the results of impurities in the water supply is tremendously important in the present emergency; so that special consideration must be given to the protection of the purity of the water supply.

Manifestly, it is not possible to prevent any possibility of contamination but a great deal can be done to get assurance against any likelihood of contamination. The War Department, the Office of Civilian Defense and the Public Health Service in planning water security programs, recognize the urgency and necessity of maintaining the purity of vital water supplies. They realize that systems that have been entirely adequate in normal times should be gone over and carefully studied to see whether there is any need for repairs; that the measures taken be emphasized perhaps to be sure that any accidental or intentional contamination will be taken care of by an excess of chlorination, or some similar precaution. Finally, that the personnel having access to the domestic water supply facilities, the personnel that could contaminate it intentionally, be very carefully identified; their loyalty looked into; their dependability looked into; and their trustworthiness assured.

Integration of Program

The Office of Civilian Defense is a body which takes all of this experience and tries to find a solution by which it can be best applied in this country of ours under our American institutions and our form of government. It is a central office that is struggling particularly with the shortage of trained medical personnel throughout the country. In the Emergency Medical Service, it has tried to organize such medical personnel as is available in such a way that it may be most useful to the community; it is trying to organize certain chemical personnel in order to help, and advise, and assist, the civilian population in protecting itself against the possible eventual use of war gases against it; it has set up a small sanitary engineering personnel to assist domestic water systems and similar problems throughout the community.

I have tried to explain to you what is meant by the Facilities Security Program. I hope I have been able to clarify our activities without boring you too much with accounts of my own activities.

The War's Effect on English Local Government

By Arthur Collins

IT is a pleasure to me to be given this opportunity of meeting our brethren in the water supply undertakings of the United States. We have so many things for which to thank America that we welcome any opportunity of expressing that gratitude, and I shall take occasion during the course of my talk to give you some indication of the way in which we are benefiting by your good will, your good nature and your generosity.

We all are particularly interested in the subject of water. Water is a curious commodity in that it is internationally in use, and yet it is not the subject of international import or export, nor is it subjected to tariffs. It is a universal commodity in which the problems are pretty common, pretty much the same no matter what the country is to which we are applying our minds.

It is true that its place, if any, amongst the potential, potable liquids in use by humanity is in some doubt and it is a very arguable point amongst Scotsmen as to whether it has any place amongst drinkable substances at all; but certain it is that our experiences in Great Britain during this time of war have underlined, if ever the matter did need underlining, the vital importance of water in a country subjected to aerial bombing.

Indeed, I would go so far as to say that it was due to the abounding efficiency of the water undertakings of every locality in Great Britain, and upon the unselfishness, the devotion and even the bravery of many water department officials, that our country was able to come through this trial.

Preparation for War

Now in order to bring the water aspect of this matter of public administration into its proper place, it is first I think desirable, if not essential, that I give you some idea of the background in which the water undertakings of our country have for some time been functioning.

To begin a little earlier than perhaps you might expect me to begin, I must first point out to you that we were prepared for air warfare from the time of Munich. We knew it was coming. We had seen the attitude of the German rulers to all nations which couldn't defend themselves or were not thought capable of defending themselves and we knew. We were, therefore told, as far as could be gathered from experiences in Spain, what bombing was like upon cities and communities, and we had observers in Spain

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An address given on June 17, 1943, at the Cleveland Conference by Arthur Collins, of Westminster, England, Speaker, British Information Service, New York.

who took pretty good notice of what bombing was like, and we prepared ourselves accordingly.

Now the Germans have been told that not a bomb would drop upon Germany. That was said to them by Goering. There is a difference there, you know, in the way in which you receive blitz when you have been told it is coming and you have prepared, and on the other hand, when you have been told it is never going to happen. So we were prepared.

We had issued gas masks to every one of our 45,000,000 population. We had equipped ourselves with all kinds of material—hundreds of thousands of fire pumps, sirens by the thousand, rest centers for the homeless, and steel shelters for the care of families (shelters buried half in the soil in the backyard and earthed over) which have been a Godsend. Morrison shelters, so-called, are in table form, steel framed, and give shelter inside the home. In these shelters a family may just about get in inside, and although they may have the house on top of them, they are at any rate not suffocated unless by dust, which is a very terrible consequence of blitzing.

Bombing Damage

Now let me give you some idea of the conditions in some of our cities with which our water authorities have had much to do, and with which they have dealt as effectively as any other branch of our fighting agencies.

In London, out of 2,500,000 homes, 1,100,000 have been damaged or destroyed, not to mention the docks and industrial buildings, banks, commercial houses, churches, chapels, hospitals; anything that is a target. By the way, in London we have had 375,000 homeless people to deal with.

In Coventry there were 70,000 houses hit out of 82,000. In Portsmouth, 65,000 out of 70,000 houses were knocked out. And so I might go on with practically all our industrial centers and even our little villages; for if there is one target—and I speak I hope with not too much bitterness when I say it—if there is one target more than another which a German who can't get past our defenses loves to attack, it is a village school or church.

Planning Water Works

Now as I say, we have had conditions of this kind to deal with and they have created for us a great many problems. From the water department point of view I propose very briefly in the limited time at my disposal, to recite for you a few of the conditions, or the treatments perhaps I should say, of the conditions which this bombing *bust* created. The war has been of benefit in one way—in showing us the value of close and detailed planning of all the water works in the area.

We had not previously realized that the placing of a gate control at a point here instead of at a point there might save the lives of numbers of people. Let me give you an illustration: Amongst the various types of shelters which we employed, we must include the underground railways, the subway transport systems of London, which you know run 90 to 120 ft. below the ground. They were thought pretty safe places. It didn't occur to any of us (at any rate I never heard anybody express it; indeed, I think I am safe in saying they did not) that where there is a station for any underground transport system there is bound to be a very substantial subway connection for water mains, gas mains, electric

mains, and the like. The very location of a station is determined by the center of gravity of the population surrounding it, and so likewise is the water main service.

Now these shelters were very popular, for women and children particularly. (For a man to be seen in a shelter was no credit to him. His job was upstairs, bombing or no bombing, helping in the rescue work.) One night it happened that a bomb fell on the junction of two of our biggest mains in London, right near one of these subway stations. It completely fractured both mains, and before the nearest gate control connection could be found, the shelterers (I had better not give you the number, but it was considerable; it is not in the official publications although I know it)—the people in that subway were drowned from below without any opportunity of getting out.*

And so while I could multiply these illustrations for you, it is the fact that we had never had occasion previously to weigh up carefully the place of each main and the place of each control on that main, for the purpose of considering what the effect of it might be upon fire fighting and upon the safety of the public in the vicinity.

Clydebank Incident

Now having given you this one illustration of a specific incident in water supply, let me turn to one of the extreme kind in which the whole water supply system of the town can be burst; thrown out. I refer to a little place called Clydebank, and although it is an extreme case, it is by no means uncommon.

Clydebank is a little place on the River Clyde, 20 miles from Glasgow, where our liners are built. It was said at the time that there was a new big liner on the docks ready to float. I don't know whether it is true or not. If I did, I should not be so foolish as to say, but at any rate, the Germans made a concentrated attack on it. They didn't hit the docks. (They are rotten shots, and I am not joking about that. They literally are rotten shots.) If they were as well-trained as your boys and ours, particularly in night fighting, we should have been paralyzed at times. As it was, in all the bombing and blitzing we had in Great Britain so far as I know, and I think I am pretty well informed, they never hit a dock gate all the time they were there. Well now Clydebank is a little town of 12,000 homes, a good many shipping offices, and about 45,000 to 50,000 population. One Wednesday night in March 1941, as near as my memory serves me, the community went to bed as usual. There had been no attack on the place previously. At two o'clock that morning the Germans came in force and, following their usual practice without regard to any particular target, deluged the place with fire bombs and incendiaries. The people had a bad time.

The next day the citizens and council workmen set to work to get as many of their houses as they could made habitable again, but things were in bad shape even when they went to bed the next night. The Germans decided evidently to make a good job of it. Whatever their reason was, they came again in about the same force next day, and the storm broke on that Friday morning. Out of 12,000 odd houses in

* Editor's Note: It is of interest to note, in the reference to the recent bombings in Hamburg, that a very large number of people were drowned in the collapse of a tunnel under the River Elbe.

Clydebank there were 10 intact! All the water mains had gone. Nothing was available for a fire. Wherever fires broken out, they just had to run riot. The war workers had to content themselves with getting people out of their destroyed premises, rescuing people from debris, oh, twice as deep in depth as this room. Fire rescue parties worked their way through channels about as wide as that chair, 15, 20 and 25 ft. inside underneath, with this load on the top of them, to rescue people known to be alive there and singing, waiting for rescue, with the knowledge that if these rescuers displaced one brick in their passage that let down a rafter, they who were waiting there to be rescued, and the rescuers alike, would never come out again. Those were the conditions in the water undertaking of Clydebank under which they had to set about practically to reconstruct their water supply.

In one of our largest towns, Birmingham, with a population of 1,000,000, the water mains were so badly hurt in a group of attacks that four-fifths of the population were without water for a while.

Lessons Learned

These experiences, while they may not sound particularly trying when related afterwards calmly and almost in cold-blood, have done a great deal to establish a very close and a very deep relationship between our water staff and the community and the other services of the local authorities.

We have perfected our detailed street plans of all our mains and controls. We have marked hydrants, etc., with luminous paint which is visible at night—you must remember there is no street lighting and there are complete blackouts—so all our hydrants can be found in the dark. We have standardized, as indeed we ought to have done previously and as I think perhaps America has done already, all our hose joints and all our fittings. We have fixed innumerable gate controls, especially since we had this experience of the underground that I was telling you about and we should now consider it, on the whole, not very creditable if in any blitz—and we have had quite a lot since we improved our controls—people in deep shelters were drowned. We have had quite a number of drownings in the ruins in the houses they occupied where the services have bursted. You can't help that. The water flows upward and suffocates them as they lie there in the debris. But for a main to burst and to be uncontrollable, that is, thus releasing a flow of water uncontrollable within a short period, would be regarded by us now as not too creditable.

Auxiliary Static Supplies for Fire Fighting

We have multiplied many times our surface storage of water because of the extreme difficulty of fire fighting with reliance upon the ordinary mains. I can give you quite a long account of the relationship between the water main service and the fire-fighting service, but I will just give you two instances which will show you how this necessity for enormous increased storage arose.

During the fire-bombing of a certain part of London, the firemen set about applying water from two near points and gradually connected more distant spots (there were 300 pumps wanted) on that fire which was a quarter of a mile long, each of four sides all ablaze. If you get a fire that size, it spreads

usually to about a mile because the tremendous updraft from a fire of that magnitude throws embers fully as big as this microphone I am speaking through, and about as thick, all ablaze, and they will be deposited anywhere from 400 to 600 yards away from the fire, and where they fall of course there is another fire.

Well, as the fires grew and as the buildings fell down under fire, and as further bombs fell, so these mains, these hoses, required to reach the main connections had to be enlarged until at the end of this particular fire (this is no uncommon thing) hoses were being carried in six lines—six groups—nine miles to get to the nearest water, and that was the river. They couldn't reach the water in the river on the night of this, one of our biggest fire raids, because the Germans, whether by accident or design, had selected a Saturday night when ordinarily the connection men—called the turncock men—would probably be away for the weekend and when the river was at the lowest level of the year; so they had to run nine miles with these hoses to get the water.

So we had to increase our surface water supply—the static water, we call it—and if you will go down any part of any English street at present you will find two types of reserve water supplies which (one doesn't want to be too pessimistic but you might keep it in mind if you get blitzes, especially on the coast towns over here) are, in our case, essential. We have erected steel surface containers holding on the average about 50,000 gal. in the middle of every three or four blocks, and human ingenuity being what it is, we have literally thousands of the basements of destroyed premises, with the old doorways and windows (so far as there were any) bricked up, lined with a quick-drying cement and filled with water. So, instead of seeing great numbers of houses with the debris lying about, it is all cleaned up and there are literally hundreds, nay thousands, of these basement containers of water.

We have not reached any standard figures for local surface storage compared with the distant storage but it has reached a very high proportion. I should be inclined to say myself that in every group of about a thousand or so of the population, there is about 20 gal. of water per head stored within 300 yards of the center of gravity of that population, so the total water storage is enormous. [*See* comment by General Grant at close of this paper.]

Water Quality Protection

Then next, we have introduced reserve chlorination plants all over the place. Water which never previously had wanted chlorination may have to be (and often has had to be) chlorinated the morning after a blitz. If a few high explosive bombs drop in the reservoir, or into the river, or the stream, or even down the wells, as has sometimes happened at the pumping station, the water becomes contaminated and is indeed poisonous. Many a time a sewer and a water main burst at the same spot, and mixed sewage floods the crater. So we have had to stop the supply of water throughout the mains until it is drained off, and chlorinate the water that is inflowing and in that way preserve the health of the people. I am happy to say there never has been any epidemic in any of our cities, a great tribute you know to the efficiency of the water service of a closely-built country like our, which has lost one house in five throughout the whole country, town, city and vil-

lage alike. Yes, one house in five has been destroyed or damaged.

Other Emergency Measures

So upon that vast and abnormal scale our water officials have to work. We say they have done a pretty good job, and I can only hope that from that very brief account of some of the difficulties they have had to contend with, and some of the ways they have attempted to meet them, you with your professionalism will not consider they have done badly.

Pumping Plant

All our pumping plant is, and has to be, overworked. The losses of water by fire alone have practically put every pumping plant onto a 24-hour operation basis. We keep large emergency repair squads and to see (as I have seen in London and in my little home town in Kent) an old, gray-bearded, gray-haired turncock (serviceman), standing by his valve, with bombs falling around him, with fires raging and firemen dashing about all over the place, calmly turning off his tap, standing by there until he is required to run to some other place; walking over damaged houses, through fires, even, to his next job, and not so much as turning a hair, makes you realize that there are heroes, yes, even in the streets, and that they needn't all be found in the fighting ranks.

Supply Pooling

Then next, the metropolitan supplies. All our local water boundaries have practically had to disappear. I was deeply interested in what your President told you last night when he was commenting upon the conflict, the irreconcilability perhaps is the better word, of the water supply boundary and the geographical, or the physical, or population distribution requirements. Now those artificial lines have had to quit. We have had to take over the water supply from the nearest available source, city water supply or corporation water supply, whichever it was, it did not make any difference. The water supply had to be got from where it was and boundaries just don't count. You can't ask, when a big fire takes place, whether it is on this side or that side of an artificial line. If you were so foolish as to do that and leave it to blaze away because it is on the other side of a line, the fire would undoubtedly spread to the one on the other side anyway, and both would be lost. The water is taken from where it is to where it is wanted and boundaries don't matter.

War Plant Supplies

War plant supplies give us a real conundrum. At times it has been a very hard thing to balance the water supply available between (1) the ordinary potable requirements, (2) the industrial requirements, (3) the reserve for fire-fighting purposes, and (4) the supplies required for new war plants. I don't say we have managed to solve that. I believe, personally, it is insoluble because conditions are so fluent that the arrangement you make today might be upset tomorrow, according to whether you are working a 24-hour time sheet or a 16-hour time sheet in a particularly big war plant.

War Plant Housing

War plant housing problems, too, have been with us, but here again I would like to confirm what Dr. Wolman said last night. In practice, if you do get into any trouble of this kind, it is just impossible to go and ask anybody

else either in Whitehall, with us, or Washington, with you, what you can or must do. You have got to do it, and the people to do it are the local people, and the local people can do it, must do it, and will do it. If you do not undertake it yourselves, if trouble should come, it is no answer (in our experience) to state to anybody who charges you with neglect of duty that this, that, or the other legal or statutory provision prevented you from doing what common sense dictated you should do. These conditions may arise, as I said before, with you. I don't know. I can only do my best to recite to you what our experience has been over the other side.

We have not had anything like a Pentagon. We have not had a supply of that magnitude pop down on us in a center already congested. Indeed I think all our water engineers agree that one of the worst problems you can create for the purposes of water supply is too high a concentration of the water traffic upon any one line or source. We have decentralized almost entirely all our wartime administrations. They are away in various parts of the country. But I haven't had any opportunity of studying the supply situation in a place like Washington, D.C., though I am going down there later on and I shall hope to see this Pentagon, and if I ever get out I shall have a very interesting story to tell.

Duplication of Supply Systems

Now lastly; on water supply in particular we have done all that we could reasonably do as a matter of practice in pooling inter-district supplies. We have run very extensive duplicate mains not only from one pumping station, or one service reservoir of one water corporation or city council to another, but by underground lines of some magnitude. Also, I think if you were to walk along any British city today you, as water men, would be interested to see how on the surface level of the street, running just on the edge of the curb, you would find miles and miles, literally miles and miles in any town, say, of the size of Cleveland, of cast iron eight and nine inch mains to provide duplicated services, not merely from the local pressure point on the high pressure main but running right across the boundary of the city into all the suburbs. The reason for this is not so much to provide a duplicate system of supply for an underground main that might be burst—indeed, you will imagine the overground mains are bursted more often than the underground—but to have as many alternative routes as possible to derive the supply. You will be surprised at the fewness of the casualties to the public property and personnel which those mains have caused. Everybody thought they would be breaking their necks on them in blackouts; that they would be fractured by traffic, but very few indeed have been the casualties resulting from the erection of these mains overground. They are very effective and they have saved many a life.

Public Morale

Now amidst these conditions I have just one comment to make upon public morale, and the care and readiness to put up with inconvenience which blitzing brings with it. It is not an unmixed blessing although I hope you will never have it. As to morale, I will just give you this simple illustration. In London there are nearly 10,000,000 people. Would you like to throw a guess as to the number in that population who went crazy under the blitzing, during the dropping of fifty

odd thousand tons of bombs when 45,000 people were killed and 60,000 seriously injured and taken to the hospital, and as I have told you, 375,000 homeless? Would you like to throw a guess as to the number who went crazy and were taken to mental hospitals in the worst period of twelve to fourteen months of intensity? I should very much like, if it were possible, to have a sort of ballot on this question. It would give me such an insight into the reflex of the minds of our friends in the States as to that phase; but that, of course, isn't possible. Here is the number—thirty people! I think I need say no more upon the morale side than that we have managed to stick it so far. We are hoping and trusting that although bad times may come, we may still fight the fight which lies before us.

Importance of Civilian Defense to Morale

I will close by two observations, one of which at any rate you may consider impertinent and if so, I trust you will forgive me. The other I think you may appreciate more fully.

In the minds of our officials from the Mayor down to the smallest occupant of a civic post; in the minds of our water engineers and every member of their staff, be they corporation or city engineers, there has been brought home this lesson: no matter how your boys may fight in the air, on the sea, on land, the battle will not be won, and they will not be as readily able to finish it, unless the morale at home stands up to it. We have had thousands of letters taken from the bodies of German prisoners and from German dead, from their wives and children at home, and it would be impossible to express in one word the content of those letters. They simply say that conditions, where your boys' are and where our bombing takes place, are terrible. They never expected it and they don't know how long they can stand it. That is the general strain, you see. Now the effect of that, continually applied as bombing proceeds, on the morale of the men at the front may very well be the same this time as it was in 1914–18. It is an underground, underneath, latent—I don't know quite what the right word is—influence upon morale. On the other hand, our censors have to deal with hundreds of thousands of letters from our mothers and wives and children at home to their men at the front and the general note of those letters is "You get on with the fight, Bill. We can take it. We are all right." (There is a very close bond, I might say between our street wardens and our citizens.) They say: "Now we are all right. Old Joe and so-and-so at the bottom of the street is our warden. He comes around to see us in every blitz. He helped us when we had a crack and so-and-so was hit. Our little Joe has been in the hospital, but he is as bright as a cricket. You get on with the fighting. We are all right at home."

Therefore, we do attach the greatest importance to our civilian defense work. While I do not know and you do not know when it might come, I would most earnestly commend to you the value of keeping up your civilian defense program, and particularly on the water works side, so as to be ready to bear this strain should it come.

Upon the water supply industry of this country may well depend the safety of the people and through this safety of the people, the morale of the men from the coast towns where you may be liable to attack.

Lend-Lease and Other American Aid

Finally, upon one subject I always find it difficult to speak without some little emotion. You must forgive me if I don't manage it any better on this occasion.

I refer to the gifts from this country, not only on Lend-Lease, which is, of course, vast; but from persons of good will who have supplied us with mobile canteens—ambulances, Red Cross stores, and so on. Concerning ambulances, don't let me forget those of your own women who have come over and driven them throughout all the blitzing. The Red Cross Stores, the Bundles for Britain, and oh, so many things we have received at your hands; let me tell you how deeply grateful we are for them.

If I could draw just a brief pen picture of one of your mobile refreshment canteens to show you what happens to them, I think it may suffice to explain the reason why it is difficult to speak of such matters calmly:

A blazing town or city, scarcely a house standing in the streets; firemen, policemen, and wardens ready to drop from exhaustion after 24 and 48 and even 60 hours continuous work; people rescued from homes thrown down upon them, sometimes after many hours underground in the dark and under conditions of suffocation. Mostly they are women and children, none of them white, either all completely black or gray from the dust of the debris; no sign of hair; few with clothes on, because the reaction from the blast of any good sized bomb is equivalent to thirty times the impact of a gale of sixty miles an hour upon the person, and it strips all your clothes off. Indeed, it will draw you out of the house if you are not careful, and often does.

Well, that is the situation around the mobile canteen. Many of them bodily wounded, children as well, being handed out food (by the assistance of some of your American girls, again, God bless them!), and they see stamped on the side of that van, as they drink their coffee and their chocolate, and eat a piece of cake or sandwich, "Presented to the United Kingdom" or "to the town of so-and-so," "the city of so-and-so," by "the city of so-and-so, U.S.A.," and often, it may be, "from the City of Birmingham, Alabama, to the City of Birmingham, England." I have myself seen these people, not downhearted, don't think that, but grim, determined, look up at this notice on the side of the van and say, "Thank God, we have got America with us." And it would be impossible for me to convey to you adequately the sense of gratitude that those people feel towards you and your generous hearts. It is a sad thing that it takes a war to bring two people so closely together as ours are, but this war has I think done something in that direction.

If these few and halting and perhaps disjointed words of mine, taken from my experience in the daily work of civic authority and public utility corporations in Great Britain—I am not a government official—are of any interest to you in the water supply undertaking of this country, I am more than compensated. I will only add, in conclusion, Britain stands up. Britain will continue to stand up, and we shall not let you down.

Comments by U. S. Grant 3rd

In answer to a question as to whether the OCD in the United States had made any recommendations for local surface storage for fighting fires, Major-General Grant said:

"The storage of water locally would be a real advantage because the storage reservoir, whether it is a pool on the ground or a lined excavation in the earth, could be filled up during the non-peak periods when the water is available, and might avoid a serious fire due to shortage of water if an emergency arose during the peak periods.

"As to the design of any type of tank for that purpose, we have not approved any design, because each community will solve that problem in a different way. We realize that the installation of a fairly complete water system to duplicate the regular water supply system, as is being done in many communities in England, would probably be impractical in the United States with our present shortage of materials, unless water plants happened to have the pipe and fittings available in their stocks.

"I might say that the reason the English have installed duplicate systems, is that the regular water supply systems, or at least many of them, were not designed to take care of fires. The construction of buildings in England is such that they do not have (in times of peace) fires as we do, and they had not, prior to the war, made provisions for the extra load due to fires, in addition to their water requirements, so their water supplies were very, very limited at the beginning of the war. When England had its first air raids and resultant big fires, many of their water systems simply could not carry the load. They then constructed their present rather elaborate system of local water supplies.

"Duplication of water systems has a possible value in the United States, since it would provide a supply of water near at hand for fire protection should a fire break out during a peak load when there would not be sufficient water in the regular system."

BLUEPRINT NOW!

Water and Sewage Works Development

EVERY city in North America is entitled to have—and with good management is able to pay for—an adequate, safe and satisfactory water supply and as a good neighbor to other cities—likewise, with good management—is able to dispose of its wastes in a manner that offends neither its own citizens nor its neighbors' citizens.

This is the broad premise that has activated four associations in the field of municipal sanitation to join in organizing and financing a "Committee on Water and Sewage Works Development." The associations are: New England Water Works Assn.; Federation of Sewage Works Assns.; American Water Works Assn.; and Water and Sewage Works Manufacturers Assn.

Dr. Abel Wolman, Professor of Sanitary Engineering at Johns Hopkins University, will act as chairman of the committee. Dr. Wolman is immediate Past-president of the A.W.W.A., Past-president of the A.P.H.A., Chairman of the War Manpower Commission's Committee on Sanitary Engineering Personnel and former chairman of the National Resources Planning Board's Committee on Water Pollution. The committee members in addition to Dr. Wolman are:

C. H. Becker, Mgr., Hydrant & Valve Dept., R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

E. S. Chase, Cons. Engr., Metcalf & Eddy, Cons. Engrs., 1300 Statler Bldg., Boston, Mass.

C. A. Emerson, Cons. Engr., Havens & Emerson, 233 Broadway, New York 7, N.Y.

R. W. Esty, Supt., Water Dept., 17 Hobart St., Danvers, Mass.

H. E. Jordan, Secy., American Water Works Assn., 500 Fifth Ave., New York 18, N.Y.

C. A. McGinnis, Johns-Manville Sales Corp., 22 E. 40th St., New York 17, N.Y.

S. B. Morris, Dean, School of Engineering, Stanford University, Calif.

G. J. Schroepfer, Chief Engr., Minneapolis-St. Paul Sanitary Dist. Box 3698, St. Paul, Minn.

Committee Program

Staff activities of the committee will center at the office of the American Water Works Assn., 500 Fifth Ave. New York 18, N.Y. E. L. Filby of Kansas City, Mo., has been secured on a leave-of-absence basis from his work in the Black & Veatch organization to act as Field Director of the committee work. The field contact service (to the extent possible with manpower and funds available) will

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A statement of the aims and objectives of the Inter-association Committee on Water and Sewage Works Development, approved at its August 9 meeting. This release was issued for the committee, under date of August 15, by Abel Wolman, Chairman, and E. L. Filby, Field Director.

deal with state, regional and local groups having an interest in water and sewage works planning. The committee will also sponsor a bulletin or printed promotional service (likewise limited by manpower and funds) to provide guidance in carrying on the work in local communities.

Believing that adequate water supply and intelligent waste collection and disposal are within the reach of every city, the Committee on Water and Sewage Works Development plans to stimulate the following activities in the cities of North America:

1. An appraisal of the needs for water and sewage works improvement or construction

2. The development of orderly programs for meeting these needs in an order related to their value to the city or the region

3. The preparation of detailed plans and specifications for the needs of first importance as soon as arrangements can be made

4. Consideration of, and development of methods for, funding the necessary construction

5. Re-appraisal of authority under which the contemplated projects can be carried on, as well as the legal basis for funding such operations (promotion of legislation whenever needed)

6. Definite scheduling of the construction program (immediate purchase of land and rights of way if part of the projects).

Good Neighbor Policy

A safe and satisfactory water supply is one adequate for all domestic, commercial and normal industrial needs. It is naturally also adequate for fire fighting purposes. It is not alone a safe drinking water, but should also be a pleasant tasting drinking water. In areas where the natural sources provide a hard water, it can be softened at an over-all economy in the production and end-uses of the supply. In areas where the water is so soft that without treatment, it is corrosive and destructive of mains and service pipes, correction of these conditions is practical, both technically and as a matter of economics.

An adequate sewerage system for a city contemplates not only a satisfactory collection system, but also facilities for treatment and disposal. Such will neither menace the public health nor offend its own citizens or those of its neighbor community situated further downstream. Likewise, an industry that dumps its waste into a watercourse without regard to the effects which may be caused by such procedure is not the sort of industry for a city or a region to welcome or to harbor. A "good neighbor" policy is international only in its broadest aspects. It begins in our own dooryards and shows itself best in the attitude that the modern city or modern industry adopts toward its neighbors.

Public Works Programs

Public works and made-work, or "boondoggling," are not synonomous. Public works, especially those related to water supply and sewerage, are essential and constructive parts of community progress. Likewise, all types of public works are not simply balance wheels or compensatory devices to be used only when private works are reduced. Water supply and sewerage developments go hand in hand with private works to develop a city or a region.

During the decade of the Twenties, combined private and public construction activity varied from a minimum

year's total of six billion dollars to a maximum of almost eleven billion dollars and public works ranged between one and a half and two and a half billion dollars annually. Many have forgotten those pre-depression years and, when public works are mentioned, remember only the decade beginning in 1933. This country has a recurring need for public works, as well as a sustained capacity to pay for them if they are useful public works. In the fields of public water supply and sewerage, a reasonable estimate of costs for useful new works and maintenance of existing works exceeds 300 million dollars per year for the next two decades. This is not made-work. There is nothing artificial about it. It is as much a part of the country's life, year to year, as are three meals a day to a normal human being.

Necessary Public Works

The Committee on Water and Sewage Works Development considers that its program is in accord with that of the Committee for Economic Development as well as with that of the Construction and Civic Development Department of the U.S. Chamber of Commerce. In other words, it considers that a reasonable program for development of public water supply and sewerage is good business and good municipal housekeeping at the same time. No industry wishes to risk its safety by reliance upon a public water supply that threatens failure when fire breaks out. No Chamber of Commerce can take pride in an inferior health record for its city due to inadequate water supply, nor does it want to menace the health of its downstream neighbors or cause them to hold their noses as they pass by, because of lack of proper sewage disposal facilities. We do not think that every stream in America can be made a spot for catching speckled trout, but we doubt that there is either economic or social (yes, we said "social") justification for the many streams in which no fish of any variety can live. There is a happy medium—even among rivers.

We find ourselves in profound disagreement with the idea that: "Public works are recognized as necessary *in a way.*" The kind of public works we are talking about are necessary *all the way* in a well balanced city or region. They are at the same time a part of industry and a complement to it.

What route would economic development take without a modern sanitary environment for the factories and their workers? What could civic development be if it failed to recognize the need of a city for a safe water supply and clean streams? The U.S. Chamber of Commerce takes a most progressive attitude in its "Plan Now for Future Public Works," where it tells its citizen members to "call on your city, county or state engineer. . . . Show him the list of possible public works projects in the back of this booklet, check those you think are needed, and see how this list tallies with his own ideas." In that list we find, among other useful civic works:

1. Water treatment plant expansion or construction
2. Extension of water supply systems
3. Police and fire protection systems
4. Water and river front improvements
5. Extensions to sewerage systems
6. Sewage treatment plant expansion or building.

We do not believe that we have to wait for federal aid, either for the plan-

ning or for the execution of useful public works. The federal aid policy of the Thirties was a major contribution toward the nation's recovery from a serious economic depression and did much to bring water and sewage works to communities whose depression-period need for them was great and whose ability to fund them was lacking. But the conditions of the immediate Forties differ in many ways—in particular because of the fact that both municipal construction and maintenance have deliberately been substantially deferred during the war period while national income has grown to heights never before attained. Thus, we can but feel that waiting for federal aid, either in planning or in execution of any public works, can only breed the necessity of having it; while the forthright local progress in planning as well as execution of public works, under the conditions and with the freedom in which American cities for generations carried on such work, will restore the true responsibility that every city and region has for putting its affairs in order and its public works program into effect. We perceive no substantial evidence that American cities need federal aid to put their water works and sewerage programs into action, but rather that the weight of evidence is to the contrary.

Let us differentiate between public works as a mechanism to take up the slack in private works and public works that are useful, self-liquidating and essentially a complementary part of the private works program. We have no desire to superimpose reasonably deferrable public works upon the tremendous upsurge of private works that will follow the end of the war, but we do desire that the program of needed and useful public works be put forward diligently and promptly so that such works may serve our people as they need them and not after they have needed them over-long. Water works and sewage works, their construction and their extension to all areas needing them, we firmly believe must be planned today so that the day of war's end will find them ready for construction—not alone because they are vitally required for the America of tomorrow, but because they are useful measures for combating unemployment when our armed forces are demobilized and while the reconversion of our industries to their normal peacetime operations is in progress.

Local Participation and Organization

The Committee on Water and Sewage Works Development realizes that its efforts will avail little unless there is a continuing local interest and active participation in the program. Such a local interest may best be stimulated by the formation of state committees within the component organizations of this committee, augmented by such personnel as may be locally desirable. The composition of state committees will vary somewhat according to local conditions, but, in general, might be made up as follows:

State Sanitary Engineer
State Planning Engineer, or equivalent
State Sanitary Water Board Engineer
Water Works Superintendent
Superintendent of Sewers
Sewage Plant Operator
Director of Public Works
Private Water Utility Engineer
Public Utility Commission (Water)
Insurance or Underwriters Engineer
State Water Engineer

The state committees will be appointed by Dr. Wolman's committee after consultation with the various state sanitary engineers, and such local, state committees undoubtedly will co-operate with other organizations having committees with similar objectives.

In the case of the New England area, the existing committee of the N.E.W.W.A. and the N.E.S.W.A. can function for all six New England States, probably expanding their present membership somewhat and possibly forming state subcommittees through state water works and sewage associations.

The Water and Sewage Works Manufacturers Assn. is one of the four founding associations. Perhaps the greatest impetus to the work can be given by the field staff of each manufacturer. The details are not definitely determined, but each general industry, such as the pipe industry, as represented in the association, can be organized through committees, who, in turn, can avail themselves of the services of the industry's field staff. Each industry representative can perform immeasurable good by repeatedly bringing home the message of "Blueprint Now!" to the smallest hamlet and the largest metropolitan district.

It is fully realized by the committee that the work it proposes to attempt is but a part of the general pattern of public works and that there are numerous other groups and organizations, well organized and financed, that will be furthering the general overall program of public works. The American Society of Civil Engineers, the United States Conference of Mayors, the American Public Works Association, the International City Managers' Association, the U.S. Chamber of Commerce and other non-governmental agencies are progressing in their efforts to have a cushion of public works ready for postwar days and are aggressively promoting their programs. State governmental agencies have been authorized, financed and are now actively functioning, as in New York, to attain similar objectives. To these and other groups with similar broad objectives, the Committee on Water and Sewage Works Development pledges its active co-operation and willingness to work in any and every way possible. Our slogan "Blueprint Now" may be freely used. The water and sewage works sector upon which we will concentrate our efforts, is but one along the postwar battlefront and we are mutually dependent upon all forces to the end that this worthwhile program be successfully accomplished.

BLUEPRINT NOW!

Domestic Water and Dental Caries

By H. Trendley Dean

THE undesirable dental effects associated with the use of domestic waters containing excessive amounts of fluorides are well known. A few years ago (1–3) attention centered around the quantitative relationship between the use of fluoride-containing domestic waters and the amount and severity of endemic dental fluorosis (mottled enamel). Concentrations of about 1 ppm. or less, were found to be below the mottled enamel threshold and little attention was paid to them.

Recent epidemiological studies (4, 5) of dental caries (decay) rates associated with the use of waters, the fluoride (F) concentrations of which were between 0.0 and 1.0 ppm., have opened a broad field of endeavor undreamed of a few years ago. Today much accumulated evidence indicates that small amounts of fluoride probably contribute to optimal dental health. The practical significance of these findings, especially to cities now using fluoride-free water, warrants serious consideration.

The potential consequences of these findings are threefold: (a) an important public health advance in the field of dental hygiene; (b) reorientation of the problem of dental needs, the future distribution of dental practitioners, the type of dentistry they will be called upon to practice, and other as yet unforeseen developments, and (c) an enlarged public health role for the water works profession.

The past triumphs of environmental control, largely in the field of bacteriology, have been notable. The inherent possibility of a new advance in environmental regulation through chemical control challenges the best scientific leadership in dentistry, sanitary engineering, and water chemistry.

In this paper, after briefly touching on the dental caries problem, I shall attempt to present some of the evidence pointing to the possibility of partially controlling, through the medium of the public water supply, what is frequently termed the most prevalent disease of civilized man, dental decay.

The Dental Caries Problem

The control of dental caries is the fundamental problem of modern dentistry. Those charged with the responsibility of planning dental health programs are appalled at the very magnitude of the problem. Among civilized people few individuals escape its attacks, in most instances not one

A discussion of the possibility of reducing dental caries through low fluorination of the public water supply, presented on June 17, 1943, at the Cleveland Conference, by Dr. H. Trendley Dean, Senior Dental Surgeon, U.S. Public Health Service, Division of Infectious Diseases, National Inst. of Health, Bethesda, Md.

tooth but many being affected. The problem is further complicated by the fact that dental enamel once injured is incapable of self repair. Thus, carious defects tend to accumulate at a rapid rate and insofar as the general population is concerned there seems no practical means of handling this load with existing professional facilities and knowledge.

With the sole exception of the teeth and their surrounding structures, the treatment of human disease falls within the province of medicine proper. The need for corrective measures in the oral cavity, however, is so great that the American dental profession, now grown to approximately 70,000 practitioners, finds that dental caries is developing faster than remedial work can be rendered. Attention may again be called to the fact that of the first 2,000,000 men examined for the Army, the chief single cause for rejection for general military service was dental defects (6).

During 1941 about $500,000,000 was spent for dental services in the United States (7). When one considers that the major portion of a dentist's time is devoted to repairing either the ravages of dental caries or its numerous sequelae the expanding economic, social, and hygienic features of this problem may be realized. And, despite this vast expenditure, these services were rendered to a portion of the population only, the majority of the people receiving either no dental service or merely extractions.

The chief hope of meeting the problem of dental needs of the entire population lies in drastically reducing the incidence of dental caries in the population. A decade ago the postulation that dental caries might be subject to mass control would have labeled its originator an unbridled visionary. Today, the unprecedented disclosures of the relationship of fluorine to dental caries indicates that it has a logical scientific foundation.

Early History of the Fluorine-Dental Caries Hypothesis

The fluorine-dental caries hypothesis is by no means novel; it may be traced with certainty back to the late 19th century. Assuming that fluorine gives hardness and lasting quality to tooth enamel and protection against caries, Erhardt (8) in 1874 recommended potassium fluoride pastilles particularly for children during dentition and for women during gestation. He comments that such procedures had been recommended in England several years previously. In 1892, Crichton-Browne (9) speculated on the possibility that the marked increase in the prevalence of dental caries in the England of that time might be due, at least in part, to a dietary fluorine deficiency associated with the introduction of the modern roller mill process in flour making. No chemical data, however, were reported in support of this surmise.

In 1897 Michel (10) reasoned that because of the bactericidal and anti-enzymatic properties of fluorine, the resistance of a tooth to decay might be influenced by its fluorine content; no chemical differences, however, were shown between the fluorine content of the carious and non-carious teeth. Two years later Hempel and Scheffler (11) reported that non-carious teeth contained more fluorine that carious teeth. The doubtful accuracy of the analytical methods then available and the absence of a suitable technical method of separating dental tissue, such as enamel

and dentine, justify questioning many of these earlier findings.[1]

Another to theorize that sound teeth probably contain more fluorine than carious teeth was McClendon (12) in 1923,[2] a view finding scientific support in the 1937 work of Armstrong (13) who, using modern methods of chemical analysis and separating the enamel and dentine, found that the enamel of caries-free teeth contained more fluorine than the enamel of carious teeth. This work will be discussed in more detail later.

In 1936 Fosdick and Hansen (14) in connection with experiments in which powdered human tooth enamel was shaken with saliva, observed that when the saliva was preserved with sodium fluoride, there was no solution of the enamel. These workers noted that "it is interesting to speculate on the possible relationship of fluorides in fermentation and the reduced susceptibility of mottled enamel to decay."

Long before the causative factor of mottled enamel was discovered in 1931 (15–17), mottled enamel investigators (Black (18) and McKay (19) as early as 1916) had commented on the lessened prevalence of dental caries in endemic mottled enamel areas. In 1916 and again in 1925 (20) McKay called attention to the fact that despite their defective structure, mottled enamel teeth were not more susceptible to dental caries than teeth not so affected. In his 1925 article, McKay made the following observation:

> "During his first contact with this lesion in any general way in an endemic district, Dr. G. V. Black made particular mention and note of the fact that the incidence of caries in mottled enamel was no greater than in 'normal' enamel, and it has been repeatedly noticed in the examinations of afflicted districts during the past ten years, not only by myself but by others, that there was a curious absence of decay. This fact was only recently commented upon by the examiners in a very large endemic district in Texas."

The qualitative aspects of this phenomenon have also been commented upon by workers of other countries: Masaki (21) in Japan, Ainsworth (22) in England, and Erausquin (23) in the Argentine.

Early efforts to learn more of this particular phenomenon began in the Twenties.

Early Mottled Enamel-Dental Caries Studies: In that period prior to the discovery that fluorine is the etiological factor of mottled enamel, two attempts to study specifically the mottled enamel-dental caries relationship were made. The first, in 1929 by Bunting, Crowley, Hard, and Keller (24) was made at Minonk, Ill., a community whose domestic water supply was found by Elvove (25) several years later, to contain 2.8 ppm. of fluorides (F). No conclusions were drawn from this study other than "the behavior of dental caries

[1] The difficulty of getting enamel free from other dental tissue, discrepancies in analytical results, etc., were definitely problems still needing solution at that time (Tomes, C. S. On the Chemical Composition of Enamel. Jour. Physiol., **19**: 217 (Mar. 6, 1896).) The indispensable and reliable methods of epidemiological procedures, which have so clearly delineated the fundamental aspects of this phenomenon within the past decade, had not yet been developed. These 19th century references, consequently, are largely of historic interest only.

[2] The lectures of Hurty at the Indiana Dental College (now the Indiana Univ. School of Dentistry) on the relation of fluorine to good tooth enamel probably anticipate this date. (Rice, T. B. *The Hoosier Health Officer.* Chap. X. "Hurty and the Indiana Dental College." Month. Bul. Ind. State Board of Health, **42**: 229 (Oct. 1939).)

and the presence of *B.* [*Lactobacillus*] *acidophilus* in the mouth are somewhat different to those which exist in other localities." These workers commented that the extent and activity of dental caries were remarkably limited, the great majority of cavities consisting of small pit and fissure lesions which seldom extended beyond that stage. The remarks of Bunting and his associates in 1928, "that there may be some principle in the drinking-water which either inhibits the activity of dental caries or protects the teeth from injury," takes on an almost prophetic significance in the light of findings reported in the past few years.

A year later (1929) McKay (26), who had collaborated with Bunting and his associates in the Minonk, Ill. study, attacked the hypothesis that "defective" enamel structure predisposed to dental caries by citing as evidence the observation that mottled enamel teeth, which probably constitute "the most poorly constructed enamel of which there is any record in the literature of dentistry"[3] do not appear to show any greater liability to dental caries than do normally calcified teeth. McKay's report referred to studies at Minonk, Ill., Bauxite, Ark., Towner, Colo., Bruneau, Idaho, and the Pima Indian School at Sacaton, Ariz.

[3] The reader should remember that when McKay comments on the poorly constructed type of enamel observed in these places, he was probably concerned with the more severe types of dental fluorosis associated with the use of fluoride waters of comparatively high concentration. In very recent years it has been shown that the inhibitory effects of fluoride waters with respect to dental caries attack are operative even at fluoride levels below the range of the mildest manifestations of dental fluorosis that are of public health significance.

Required Studies in Co-ordinative Fields

As has been indicated, the hypothesis is not entirely new. The facts to demonstrate it were available for many years; Aurora, Ill. and Colorado Springs, Colo., for example, have been using their present type of water for nearly a half century. Like an exposed film in a camera, the outline of the picture remained hidden until the proper developing medium was made available. Much time passed and the work of many investigators, often in fields far removed from the study of fluorine and dental caries, was required before the necessary quantitative means of measuring these differences were developed and co-ordinated.

Particularly was this true concerning the part played by epidemiology in the solution of this problem. During the past decade notable changes occurred in the measurement of dental caries experience (27); attention centered on the quantitative estimation of the degree of affection in the tooth population itself. From these studies of the topography of dental caries attack certain epidemiological constants developed. These efforts in quantitative reporting, as in the case of mottled enamel (28), made for a fuller understanding of the dental caries problem. The dental caries experience (prevalence) rates provided one means of recognizing and roughly measuring marked variations in the intensity of dental caries attack on populations. In this respect, however, much still remains to be done. Four cardinal points, unavailable to earlier workers were responsible for the clarity of the epidemiological picture as now known.

1. Refinements in measuring dental caries experience involving prevalence

rates specific for age, sex, and color, the knowledge of which, in turn, limits comparison to tooth populations comparable respecting exposure to risk of happening (27, 29).

2. Elimination of the "circulation factor," or confining all observations to those continuously exposed to the specific environmental factor under investigation (the common water supply) (28).

3. Development of analytical chemical methods permitting water analyses accurate to 0.1 ppm. of fluoride (F) (25), and

4. Development of quantitative methods for estimating the number of *Lactobacillus acidophilus* in the saliva used as an index of dental caries activity (30).

In the biochemical field much the same evolutionary processes were developing. During the time that the epidemiological tools were being forged with the aid of numerous field studies, similar improvements and developments were being made in the laboratory. Methods of separating enamel and dentine were developed so that these tissues might be analyzed separately and their fluorine content determined by methods having a high degree of accuracy.

The 1937–1939 Period

In any history of the fluorine-dental caries relationship the years 1937–1939 will be conspicuous. During this two-year interval numerous studies in epidemiology, biochemistry, and animal experimentation were reported. Noticeable was the fact that, although they were from independent investigators working in different institutions, the findings of each were in general harmony with all of the others. These studies and results may be summarized as follows:

Epidemiology: An inverse variation between endemic dental fluorosis (mottled enamel) and dental caries was pointed out by Dean in 1938 (31). A study of 236 nine-year old children with a verified continuity of exposure to the several water supplies being studied, indicated a higher percentage of caries-free children in those communities whose water supplies were characterized by a higher fluoride content. This relative freedom from dental caries was present: (a) in deciduous teeth as well as the permanent teeth, and (b) *whether or not the teeth showed macroscopic evidence of mottled enamel.*

The relationship between these two variables in larger and general population groups was further studied by an analysis of dental caries prevalence rates recorded for South Dakota and Wisconsin children as reported in Public Health Bulletin No. 226. In Wisconsin, for instance, 4945 white children, twelve to fourteen years of age in eight cities were examined. In seven cities where the public water supply contained fluorides in amounts ranging from 0.0 to 0.2 ppm., the amount of dental caries was double and treble that recorded for Green Bay where the water supply contained 2.3 ppm. of fluorides.

In the autumn of 1938 (32) a study designed to further test this hypothesis was made in north-central Illinois, the principal cities being Galesburg and Quincy. In planning the study, account was taken of such variables as age, sex, diet, latitude and sunlight intensity, and composition of the population. The clinical examinations were limited to twelve, thirteen or fourteen

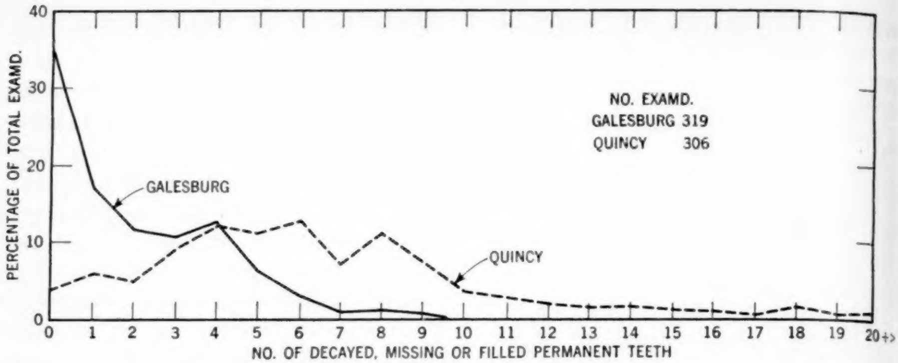

FIG. 1. Variation in the Amount of Dental Caries in 12–14-Year Old White Children of Galesburg and Quincy, Ill.

TABLE 1

Distribution of the Occurrence of Multiple Attacks of Dental Caries Among Selected 12–14-year Old White School Children of Galesburg and Quincy, Ill.

Permanent Teeth Attacked by Dental Caries (Decayed, Missing or Filled) per Child	Frequency Distribution or No. of Children Attacked		Percentage Frequency Distribution		Percentage Frequency Distribution (Cumulative)	
	Galesburg	Quincy	Galesburg	Quincy	Galesburg	Quincy
0	112	12	35.1	4.0	—	—
1	55	18	17.2	5.9	52.3	9.9
2	37	16	11.6	5.2	63.9	15.1
3	34	27	10.7	8.8	74.6	23.9
4	40	36	12.5	11.8	87.1	35.7
5	19	34	6.0	11.1	93.1	46.8
6	9	38	2.8	12.4	95.9	59.2
7	5	22	1.6	7.2	97.5	66.4
8	5	33	1.6	10.8	99.1	77.2
9	3	21	0.9	6.9	100.0	84.1
10		11		3.6		87.7
11		7		2.3		90.0
12		6		2.0		92.0
13		5		1.6		93.6
14		5		1.6		95.2
15		3		1.0		96.2
16		3		1.0		97.2
17		1		0.3		97.5
18		5		1.6		99.1
19		1		0.3		99.4
20 or more		2		0.6		100.0
Résumé:						
None	112	12	35.1	4.0		
One or more	207	294	64.9	96.0		
Total	319	306	100.0	100.0		

* Dental caries experience rate (permanent teeth) per 100 children examined: Galesburg, 201; Quincy, 633.

year-old white children with continuity of risk of exposure to the variable being studied (the water supply). About 70 per cent of the continuously exposed white population of the three age groups mentioned were examined at Galesburg and Quincy. The Galesburg ground water supply contained 1.8 ppm. of fluoride; the Quincy supply, obtained from the Mississippi River, 0.1 ppm.[4] The dental caries prevalence in the 306 children at Quincy was well over three times as high as that observed in the 319 Galesburg children. Using the proximal surfaces of the four permanent superior incisors as a basis of measurement, there was fourteen times as much proximal caries in Quincy as in Galesburg. Bacteriologically, the epidemiological aspects of oral *Lactobacillus acidophilus* in saliva closely reflected the observed difference in caries prevalence rates between the two cities.

The findings at Galesburg and Quincy furnished a striking example of a marked variation in the intensity of dental caries attack between white urban school populations, the only recognizable variable being the difference in the fluoride content of their domestic water supply. Some of these differences are shown in Table 1 and Figs. 1 and 2. While these findings gave considerable impetus to the general principle of mass control of dental caries through the public water sup-

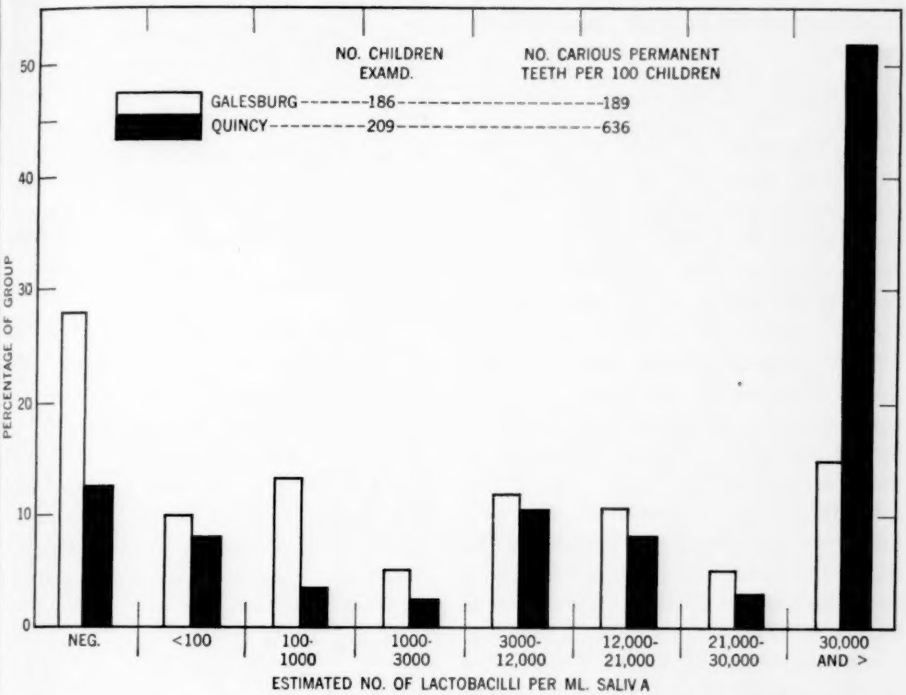

FIG. 2. Percentage Distribution of Lactobacilli in the Saliva of the Groups Examined at Galesburg and at Quincy, Classified According to the Estimated Amount

[4] The original report (32) gives 0.2 ppm. of F and was based on the analysis of a single sample; the arthmetic mean of 12 consecutive monthly samples, 1940–1941, was 0.1 ppm. of F.

ply, it was felt that judgment should be withheld until it was determined whether or not the factor (presumably fluoride) inhibiting the initiation of dental caries was operative at a level sufficiently low to eliminate even the milder forms of endemic dental fluorosis. A study to answer this crucial question was reported in 1942 (5); it will be described in detail later in this paper when the results of studying twenty-one cities of four states are recorded.

Biochemistry: Until results were presented by Armstrong (13), and Armstrong and Brekhus (33) in 1937 and 1938 with respect to the fluorine content of human enamel and dentine, there was no certain evidence of any relationship between the chemical composition of enamel and dentine and the tooth's resistance to dental caries. These workers found that between sound and carious teeth there were no compositional differences in the major components, calcium, phosphorus, magnesium, and carbonate. A significant difference, however, was noted in the fluorine content. According to these workers the enamel of sound teeth has a mean fluorine content of 0.0111 ± .00203 per cent fluorine, while enamel of carious teeth contained 0.0069 ± .00111 per cent fluorine. Dentine showed less striking differences; dentine of sound teeth equaled 0.0169 per cent fluorine, as compared with carious teeth dentine which contained 0.0158 per cent fluorine. Even in the same individual Armstrong found sound enamel to contain approximately 40 per cent more fluorine than carious enamel.[5]

At the close of this period appeared one of the early papers designed to elucidate the mechanism by which fluorine inhibits dental caries attack. This paper by Volker (34) might be interpreted to indicate that the enamel with more fluorine is more resistant by virtue of a lessened solubility.

Animal Experimentation: Previous to 1938 much data with respect to dietary variations including minerals, vitamins, fats, carbohydrates and proteins as factors in the rats' response to caries producing diets had been reported. While it was possible to a greater or lesser degree to modify experimental rat caries by these factors, there was no suggestion that any of these factors offered much prospect as agents in a far reaching control of human dental caries.

In 1938 Miller (35) showed rather strikingly that induced rat caries may be largely prevented by additions of sodium fluoride or calcium fluoride, or iodoacetic acid to the rats' food and water. Thus Miller demonstrated that it is possible to inhibit induced caries in rats by means of two substances noted for their anti-enzymatic properties; Miller's results with respect to fluorides were shortly after confirmed by Finn and Hodge (36) and by numerous workers since. In connection with Miller's experiment, Harrison (37) reported certain bacteriological studies concerning the oral flora of the rats. He found a temporary reduction of lactobacilli from 18 per cent to 3 and 1 per cent in terms of the total acidogenic organisms associated with the iodoacetic acid and fluoride feeding, respectively. Another pertinent study at this time was that of Hodge, Luce-Clausen and Brown (38) indicating that Lilly's results (39) (marked reduction in rat caries on a

[5] *See also:* ARMSTRONG, W. D. & BREKHUS, P. J. J. Dent. Res., **17**: 27 (Feb. 1938); BOWES, J. H. & MURRAY, M. M. Biochem. J., **29**: 102 (*Pt. 1*) (Jan. 1935) *and* Brit. Dent. J., **60**: 556 (1936).

casein diet) were explainable on the basis of contamination of the commercial casein with fluoride.

Late in 1939 Cox and his associates (40) reported an interesting experiment which purported to show that caries resistance could be "built into the enamel." The offspring of rats fed sodium fluoride, sub-mottling dosage, during gestation and lactation showed significantly less caries than the offspring of animals not fed fluorides. In this experiment, these workers point out, the fluorides apparently reached the young animals through physiological routes, placental and mammary transmission. No fluorine was given to the rats after they were placed on a caries producing diet.

The mechanism by which fluoride inhibits the initiation of dental caries still provides a fruitful field for discussion and investigation. Very recent studies by Armstrong (41) and McClure (42) indicate that the mode of action may follow one of several paths. Much experimental work remains to be done before the mechanism of the anti-caries effect of fluoride is understood.

At the close of this period [6] one of the pertinent practical questions asked was: Are there domestic waters low enough in fluorides to avoid the mottled enamel problem but still sufficiently high to markedly reduce the amount of dental caries? A discussion bearing on this question follows:

An Epidemiological Study of 21 Cities of 4 States

The 1937–1939 findings stimulated an unusual amount of research in the fluorine-dental caries field. These studies have made various aspects of the phenomenon clearer and more intelligible, but the limitation of this paper precludes their review in detail and a discussion of their relationship to the general epidemiological picture.

After the completion of the Galesburg-Quincy study it appeared that a relatively extensive epidemiological study was needed to determine how low a fluoride concentration in a public water supply would be found associated with relatively low dental caries experience rates.

For a clearer understanding of the findings to be presented later, an account of some of the more important technical methods utilized will be given. As in other epidemiological studies, each problem presents its own varying sets of conditions, those recognizable necessitating careful appraisal

[6] Other articles appearing during the 1937–1939 period were: Arnim, S. S., et al. (43); Klein, H. and Palmer, C. E. (44); Deatherage, C. F., et al. (45); Cox, G. J. (46) and Jordan, H. E. (47).

The literature since 1939 is so voluminous as to preclude its review in a paper basically of an epidemiological nature. The interested reader should refer first to the monograph: "Fluorine and Dental Health," F. R. Moulton, ed., pub. No. 19, Am. Assn. Advancement of Science, Science Press Printing Co., Lancaster, Pa. (ref. 48).

Some of the more recent papers bearing on the fluorine-dental caries hypothesis and not referred to in the monograph cited (ref. 48) are: Brun, G. C. et al. (49); Hodges, P. C., et al. (50); Lukomsky, E. H. (51); McGibony, J. R. (52); McClure, F. J. (53); McClendon, J. F., and Foster, W. C. (54); Cheyne, V. D. (55); Bibby B. G. (56); Cheyne V. D. (57); De Eds, F. (58); Arnold, F. A., Jr., et al. (59); Armstrong, W. D., and Knowlton, M. (60); Kemp, F. H., et al. (61); Machle, W., et al. (62); McClendon, J. F., et al. (63); Shils, M. E., and McCollum, E. V. (64); Hodge, H. C. (65); Black, A. P. (66); Armstrong, W. D. (67); Marcovitch, S., and Stanley, W. W. (68); MacIntire, W. H., et al. (69); Anderson, G. W. (70); Ast, B. D. (71); and McClure, F. J. (72).

prior to the inauguration of the study. The methods used can be given only with the utmost brevity. For a detailed exposition recourse should be had to the original articles (4, 5).

Age and color: All examinations were limited to twelve to fourteen year old white school children, age being defined by last birthday. Selection of this segment of the school population permits the examination of a group in whom a high percentage (approximately 94 per cent) of the permanent teeth [7] have erupted. The results of an examination of school children of higher age groups introduces the question of representativeness of the sample because of the increasing percentage of children in the higher age groups not attending school. The negro was excluded from the study because this racial group seems to show a lessened tendency to experience dental caries attack.

Selection of study groups: The groups examined generally represent all twelve, thirteen and fourteen year old white public [8] school children continuously exposed to the variable under investigation (the public water supply). All public schools in each community having a seventh, eighth, or ninth grade were included in the study. If questioning elicited information which disclosed breaks in continuity of exposure (thirty days in any calendar year excepted) the child was eliminated from further study.

Continuity of exposure: Dental caries being a non-healing lesion, a single clinical dental examination of twelve to fourteen year old children can merely record the amount of dental caries experienced by that group during the post-eruptive life of the teeth examined. The observed lesion may have developed at any time during the post-eruptive life of the tooth examined. At what particular time during the post-eruptive tooth life the observed lesion developed cannot be determined on the basis of a single examination in this age group.

The movement of populations, especially in the densely populated urbanized areas contiguous to the city of Chicago where part of the study was conducted, is quite marked. The water supplies of these numerous communities show considerable variation some using Lake Michigan water either purchased from the city of Chicago or procured from their own plants; others depend wholly upon the municipal ground water supply. As single clinical examinations in this age group can disclose only the amount of dental caries experienced and not when it occurred, the corollary that naturally follows demands that all observations be confined to children with continuous exposure to the variable under study (the communal water supply). Otherwise, dental caries developed several years previously in an area with a high rate might be erroneously charged to an area with a low rate, or vice versa. In order, therefore, that differences in dental caries experience might be studied correctly with respect to their relationship to the mineral composition of the public water supply, all groups compared were placed on a comparable basis of exposure to risk, age, sex, color and continuous use of the supply.

In short, population groups upon whom quantitative evaluations are computed must be subjected to two ex-

[7] Third molars excepted.

[8] At Colorado Springs and East Moline children of the parochial schools were examined in addition to the public school children.

aminations: (a) a *retrospective examination* as to the domestic water used throughout life, and (b) a *cross-sectional examination* for the purpose of measuring the effects of using such water as may be shown by the permanent teeth. The public water supply must also be subjected to a retrospective evaluation in order to learn whether any apparently relevant changes have occurred in its physical setup, source, or composition during the period concomitant with the life of the group examined.

Clinical examinations: All examinations were made by the same examiners using a mouth mirror and explorer. The personal interpretation in caries diagnosis may be subject to considerable variation between different examiners (*73, 74*); this is especially true in areas characterized by low dental caries prevalence. Attempts to equalize this variation associated with subject assessment, or at least to make such variations compensatory, in so far as group differences in prevalence rates were concerned, were made as follows: (a) Both examiners had a similar background;[9] (b) The diagnostic criteria of the two examiners were calibrated at the beginning of the study in both a high and a low rate area. (c) The examiners worked together as a team visiting each school included in the study, and each examined approximately an equal number of children in each school. The examination schedules were numbered serially, and throughout the entire study all odd numbered cases were examined by one examiner, all even numbered by the other.

[9] Both had completed in the same school a one year graduate study in children's dentistry about a month prior to the beginning of the study.

Dental caries experience (or prevalence) rate: In computing an index for showing the amount of dental caries in the population groups studied, prevalence was expressed in terms of the dental caries experience of the group. Dental caries experience (permanent teeth) is determined by totaling the mutually exclusive number of filled teeth (past dental caries), the number of teeth with untreated dental caries, the number of teeth indicated for extraction plus the number of missing teeth. When it is desired to express the dental caries experience in terms of a rate per one hundred children, the sum of the four aggregates referred to is divided by the number of children examined and the quotient multiplied by 100.

Findings: The basic findings of this study are summarized in Table 2 and Figs. 3 and 4. Probably the outstanding epidemiological characteristic of these data is the striking variation in the intensity of dental caries attack[10] as evidenced by the marked differences in the amount of dental caries experience. Considering the relative homogeneity of these populations, the methods of selecting the study groups, and the similarity of diagnostic standards used, it does not seem likely that such differences can be due to other than the mineral composition of the supply.

That the inhibitory agent is the fluoride content of the water supply seems highly probable. An inspection of the range of different fluoride concentra-

[10] The term "intensity of dental caries attack" as used in this paper may be defined as the force of the factors responsible for the initiation (or inhibition) and rate of progress (or quiescence) of the dental caries process. This force of attack (or force of resistance) is subject to considerable change dependent upon varying circumstances.

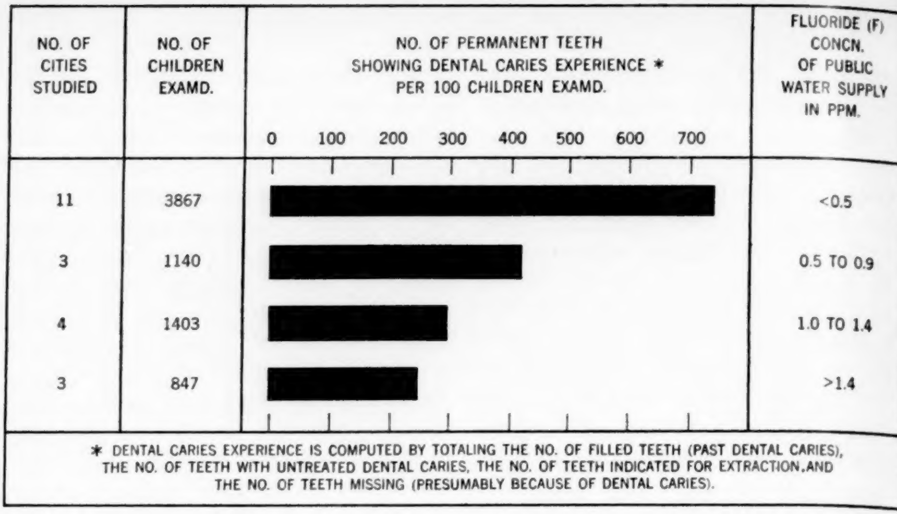

FIG. 3. Amount of Dental Caries (Permanent Teeth) Observed in 7257 Selected 12–14-Year Old White School Children of 21 Cities of 4 States, Classified According to the Fluoride Concentration of the Public Water Supply

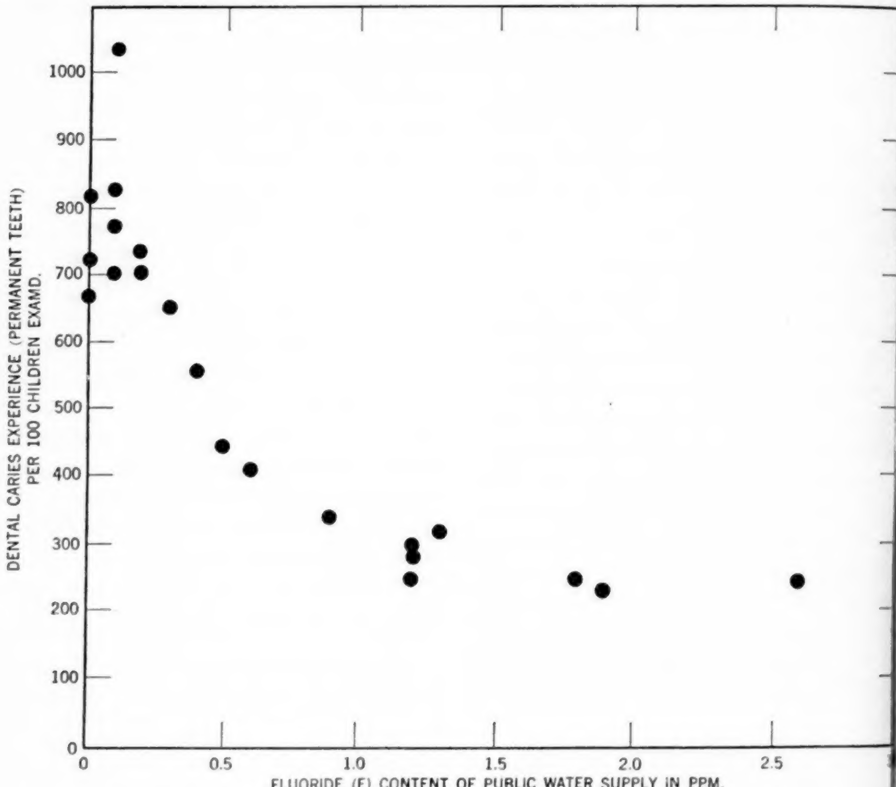

FIG. 4. Relation Between the Amount of Dental Caries (Permanent Teeth) Observed in 7257 Selected 12–14-Year Old White School Children of 21 Cities of 4 States and the Fluoride (F) Content of Public Water Supply

tions discloses an inverse relation in general between the amount of dental caries and fluoride concentration of the common water supply. Relatively low dental caries experience rates are found associated with the use of domestic waters whose fluoride (F) concentrations have a range of one or more parts per million. Intermediately, e.g. at concentrations 0.9 to 0.5 ppm., the influence is less marked than at the higher concentrations; nevertheless, the dental caries experience rates are distinctly lower than those associated with the use of relatively fluoride-free waters.

Differences in dental caries experience rates of as much as two and three times the observed minimal were not unusual; the highest rate, 1037, at Michigan City, Ind., was 4.4 times that observed in the city with the lowest rate, 236, at Galesburg, Ill. Strikingly

TABLE 2

*Summary of Dental Caries Findings in 7257 Selected White School Children, Aged 12–to 14 Years, in 21 Cities of 4 States, in Relation to the Fluoride (F) Content of the Public Water Supply**

City	No. Children Examd.	Clinical: Dental Caries Experience (Permanent Teeth): Percentage Children Showing None	Clinical: Dental Caries Experience (Permanent Teeth): No. per 100 Children Examd.		Water: Fluoride (F) Concentration of Public Water Supply in ppm.		Water: Total Hardness in ppm.	Water: Source
Galesburg, Ill.	273	27.8	236			1.9	247	Deep Wells
Colorado Springs, Colo.	404	28.5	246	244	>1.4	2.6	27	Surface (Pike's Peak)
Elmhurst, Ill.	170	25.3	252			1.8	323	Deep Wells
Maywood, Ill.	171	29.8	258			1.2	75	Deep Wells
Aurora, Ill.	633	23.5	281	294	1.0–1.4	1.2	329	Deep Wells
East Moline, Ill.	152	20.4	303			1.2	276	Deep Wells
Joliet, Ill.	447	18.3	323			1.3	349	Deep Wells
Kewanee, Ill.	123	17.9	343			0.9	445	Deep Wells
Pueblo, Colo.	614	10.6	412	416	0.5–0.9	0.6	302	Arkansas River
Elgin, Ill.	403	11.4	444			0.5	103	Deep Wells
Marion, Ohio	263	5.7	556			0.4	209	Deep Wells
Lima, Ohio	454	2.2	652			0.3	223	Impounded Surface
Evanston, Ill.	256	3.9	673			0.0	131	Lake Michigan
Middletown, Ohio	370	1.9	703			0.2	329	Deep & shallow wells
Quincy, Ill.	330	2.4	706			0.1	88	Mississippi River
Oak Park, Ill.	329	4.3	722	740	<0.5	0.0	132	Lake Michigan
Zanesville, Ohio	459	2.6	733			0.2	291	Deep Wells
Portsmouth, Ohio	469	1.3	772			0.1	80	Ohio River
Waukegon, Ill.	423	3.1	810			0.0	134	Lake Michigan
Elkhart, Ind.	278	1.4	823			0.1	220	Deep Wells
Michigan City, Ind.	236	0.0	1037			0.1	141	Lake Michigan

* Compiled from: DEAN, H. T., JAY, PHILIP, ARNOLD, F. A., JR. & ELVOVE, E. Pub. Health Rpts., **56**: 761 (1941); DEAN, H. T., ARNOLD, F. A., JR. & ELVOVE, E. Pub. Health Rpts., **57**: 1155 (1942).

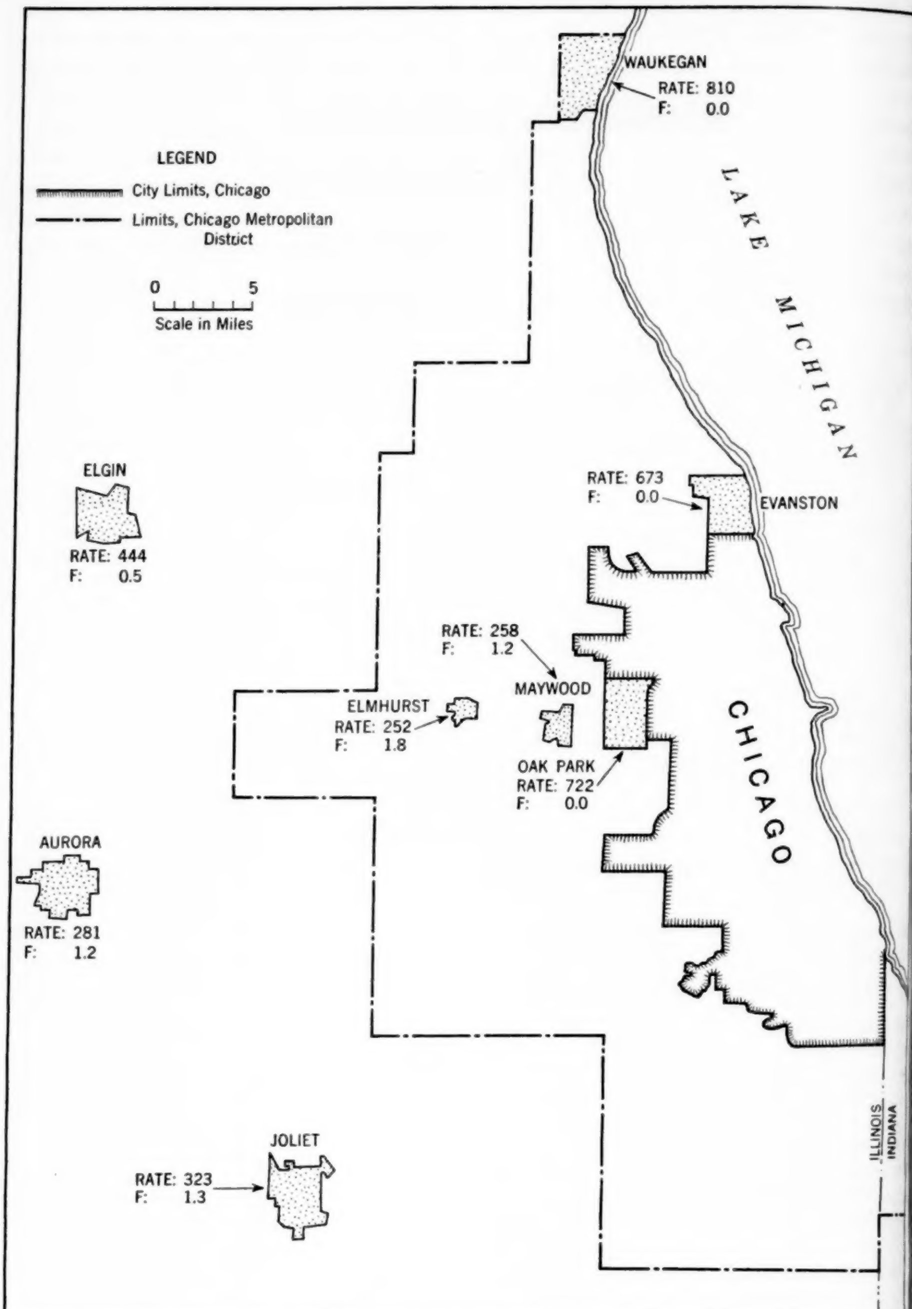

FIG. 5. Location of the 8 Suburban Chicago Communities Studied

low dental caries prevalence was found associated with the continuous use of domestic waters whose fluoride (F) content was as low as about 1 ppm., a concentration which under the conditions prevailing in the localities studied produced only sporadic instances of the mildest forms of dental fluorosis of no esthetic significance.

Interpretation of broad epidemiological studies: Speaking of interpreting broad epidemiological studies Frost (75) states that it is "requisite that the various features of distribution be considered in their combinations rather than separately, and that they be put together with such facts as are known from more detailed local studies and from experimental investigations." He further asserts that almost invariably in epidemiological studies "any single association which may be found is checked by its relation to a number of other associations and special circumstances, which will confirm or modify the significance of the single fact. . . . The interpretation, in an epidemiological sense, of any association which may be found in the local occurrence of a disease always requires that the facts be related to the whole theory of the disease."

Many of the experimental investigations pertaining to the fluorine-dental caries hypothesis have been described in the monograph, "Fluorine and Dental Health" (48) and this part of Frost's axioms seems well fulfilled. Analysis of detailed local studies invalidate any assumption that the marked differences in dental caries experience observed in the twenty-one cities studied can be explained on the basis of the hours of sunshine, gross dissimilarities in diet (water excluded), or the hardness of the water supply.

Certain studies (76, 77) suggest an inverse relationship between the amount of sunshine and dental caries prevalence; neither of these studies take into account the influence of the fluoride intake variable. In the twenty-one cities, discussed in this paper, detailed climatological data is given (4, 5) for each and it may be noted that cities characterized by high dental caries experience, e.g. Portsmouth and Middletown, Ohio, show percentages of "clear days" as high or higher than that of Galesburg, a city where a very low dental caries prevalence was observed. Among the cities studied in the Chicago suburban area were Maywood and Oak Park, communities within a one-mile radius [11] with sunshine (Fig. 5) apparently uniform. Yet, Oak Park, using the fluoride-free Lake Michigan water, shows a rate nearly three times as high as Maywood using a water containing slightly over 1 ppm. of fluoride. It might also be noted parenthetically that some communities having an abundant amount of sunshine may also be characterized by high dental caries prevalence, e.g. Key West, Fla. (78) where the inhabitants obtain their domestic water from cisterns, Haiti (79), Jamaica (80), and Panama Canal Zone (81). With respect to diet it seems reasonable to assume, especially in the Chicago suburban area, that the food habitually consumed by the populations follows a general likeness. Hence, considering the selection method used (*all* children of continuous residence) it would seem unlikely

[11] Students interested in the epidemiological aspects of water and disease may note certain basic similarities between the Chicago suburban area study and the 1892 investigation at Hamburg, Altona, and Wandsbeck.

that the marked differences in dental caries experience were due to differences in the food used in the communities. It would not seem reasonable to assume that the dietary regime (water excluded) of the 633 Aurora children was sufficiently different from that of the 423 Waukegan children to account for a dental caries experience rate in Waukegan of about three times

These studies indicated that when relatively large numbers of cities were studied, users of "hard" water had less dental decay than those using "soft" waters. Most of these studies were reported before the influence of fluoride was known and in the light of these new findings it is necessary to re-examine the old "hard" water dental decay studies because of the likelihood

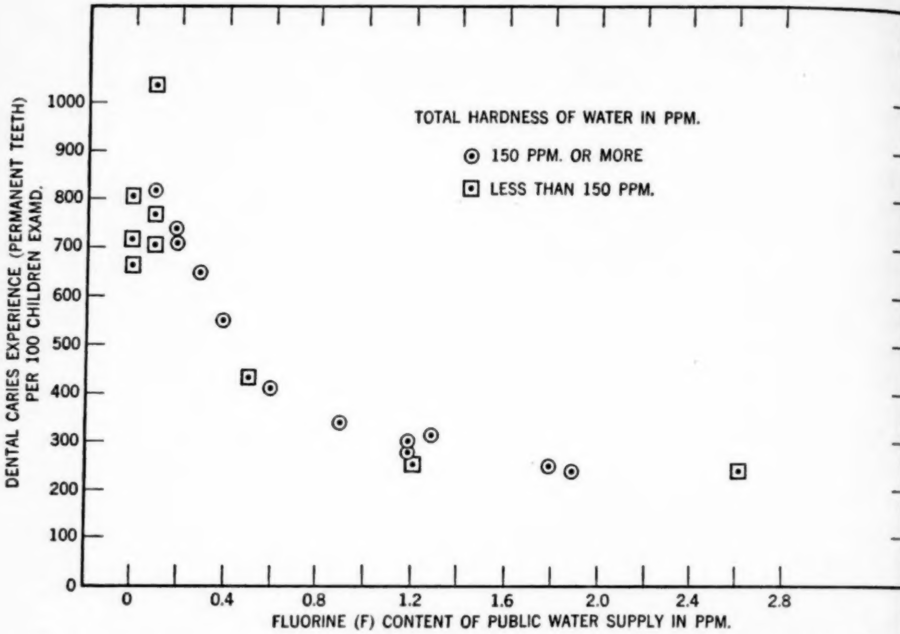

FIG. 6. Variation in Dental Caries Experience Rates Observed in 7257 Selected White School Children, Aged 12 to 14 Years, in 21 Cities of 4 States with the Fluoride Concentration of the Public Water Supply, According to High and Low Values of Total Hardness

that in Aurora (281 in Aurora and 810 in Waukegan).

During the past fifty years there have appeared a few papers indicating that an increased hardness in the drinking water is associated with a lower amount of dental caries. Chief among these reports are: Förberg (82) in Sweden, Röse (83) in Germany, Cook (84) in England, and Mills (76) and East (85) in the United States.

that the differences in the reported amount of decay were due to differences in the amount of fluorides and not to differences in hardness of water. Small amounts of fluorides are most frequently found in well waters, surface supplies being as a rule relatively free. Thus, if we compare the waters of a relatively large number of cities selected at random we are very apt to have most of the fluoride waters in the

"hard" water group and most of the "fluoride-free" in the soft water group.

Study of specific communities, however, indicates that water hardness in itself does not appreciably influence the incidence of dental caries. For example, in this study, Middletown and Zanesville, Ohio, having water supplies of relatively high hardness (329 and 291 ppm. respectively) but which are practically free of fluorides show high dental caries prevalence rates of 703 and 733 (carious teeth per 100 children) respectively. On the other hand, Colorado Springs, Colo., has a relatively "soft" public water supply, the total hardness being only 27 ppm. This water, however, contains 2.6 ppm. of fluoride; a low dental caries rate was observed, 246 (carious teeth) per 100 children. The data reported in Table 2 for the twenty-one cities studied are shown in Fig. 6, dental caries prevalence being plotted against the fluoride concentration of the public water supply with the cities divided on the basis of water supplies under or over 150 ppm. of hardness.[12] No tendency of these points to distribute themselves on the basis of hardness is apparent. To analyze these data another way the dental caries experience was plotted against the total hardness. As may be seen (Fig. 7) the plotted points are scattered at random suggestive of a very poor or non-existent relationship. When, however, the discrete

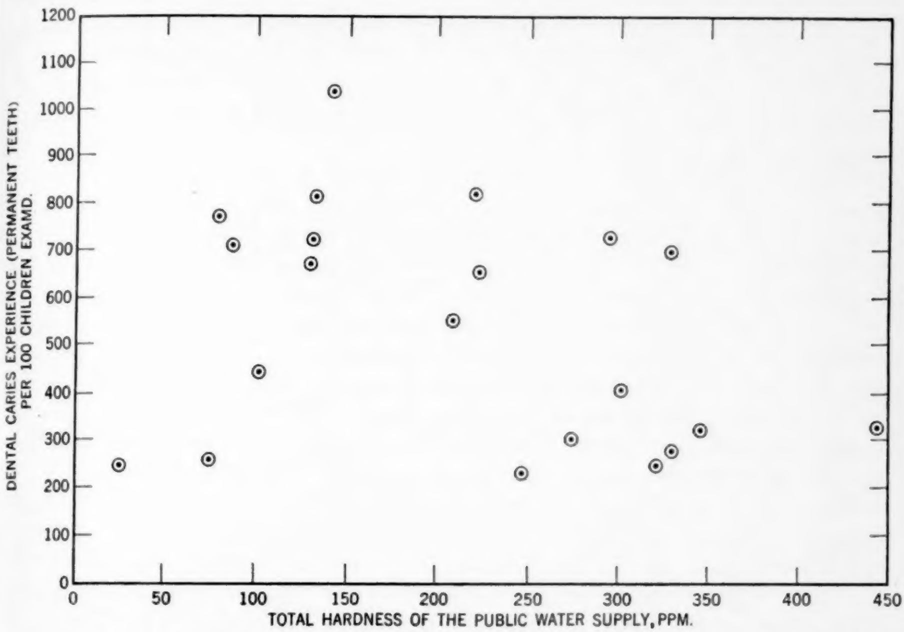

FIG. 7. Variation in Dental Caries Experience Rates Observed in 7257 Selected White School Children, Aged 12 to 14 Years, in 21 Cities of 4 States with the Total Hardness of Public Water Supply

[12] Total hardness calculated in accordance with *Standard Methods for the Examination of Water and Sewage.* Am. Pub. Health Assn. & Am. Water Works Assn., New York (8th ed., 1936).

points are connected with contour lines on the basis of whether the water contains more or less than 0.5 ppm. of F. (Fig. 8) the separation and parallelism is unmistakable.

Discussion

Consideration of the data presented warrants the inference that between certain limits there is a causal quantitative relation between fluoride domestic water and dental caries prevalence. From a practical standpoint, the basic finding of these studies would seem to be the relationship of fluoride (F) concentrations between 0.0 and 1.0 ppm. to the intensity of dental caries attack. Inspection of the range of dental caries experience associated with the use of domestic water of different fluoride concentration indicates that there is little, if any, advantage to be gained in further caries reduction by using a domestic water higher than about one part per million.[13] Fortunately at this level the disfiguring complication of endemic dental fluorosis (mottled enamel) observed among users of waters of higher fluoride concentration is not present.

On the basis of the observations made in the suburban Chicago area, Arnold (86) has recently estimated the magnitude of the beneficial changes that might occur after the requisite lapse of time were the fluoride-free Lake Michigan water supplies at Evanston, Oak Park, and Waukegan raised

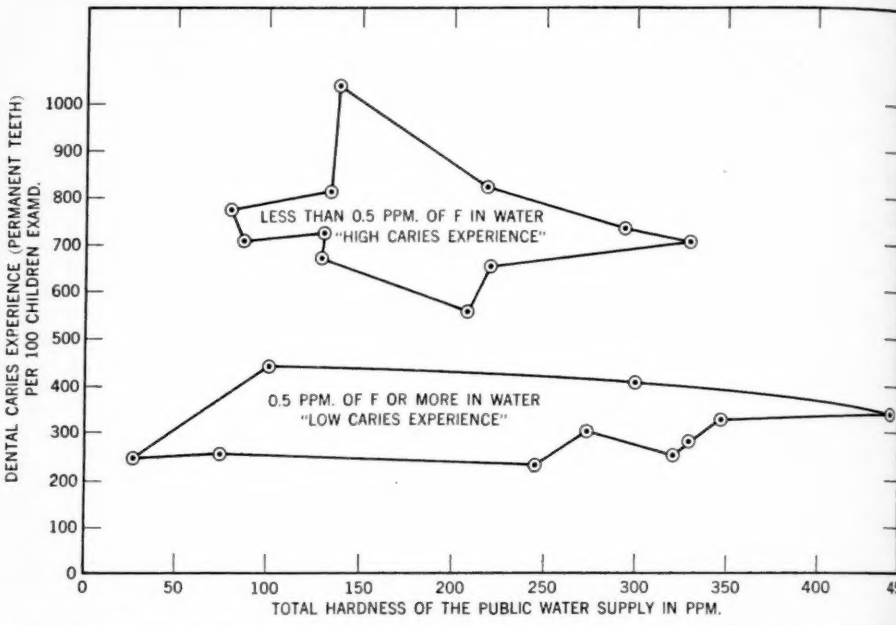

FIG. 8. Variation in Dental Caries Experience Rates Observed in 7257 Selected White School Children, Aged 12 to 14 Years, in 21 Cities of 4 States with the Total Hardness of the Public Water Supply, According to the High and Low Fluoride Values

[13] This amount is not in excess of the maximum allowed for present drinking water standards. (Public Health Service Drinking Water Standards. Report of the Advisory Committee on Official Water Standards. Pub. Health Rpts., **58**: 69 (Jan. 15, 1943).)

to about 1 ppm. of F. A comparison of the dental caries picture in the 633 Aurora, Ill., children with that of the 1008 children in the three fluoride-free communities mentioned would be expected to show:

1. About six times as many children showing no dental caries experience (caries free),
2. About a 60 per cent lower dental caries experience rate,
3. About a 75 per cent decrease in the first permanent molar loss, and,
4. Approximately 95 per cent less caries in the proximal surfaces of the four upper incisors.

Theoretically, the idea of fluorination of the domestic water supply for the reduction of dental caries prevalence appears sound. Because of its unusually high prevalence, dental caries seems particularly suited for control measures through a communal medium such as the water supply. It would not involve adding anything not already present in water supplies used daily by more than a million people in this country. Furthermore, the amount suggested, namely 1 ppm., is considerably lower than many hundreds of thousands of these people are now using daily. Much investigative work, however, is necessary before serious thought can be given to a recommendation for its general application. To determine the safety threshold with regard to possible effects other than on the teeth, carefully controlled studies must be made of populations who have used fluoride waters of relatively high concentration over a number of years.

The possibility of cumulative toxic effects of a non-dental nature at even a concentration of 1 ppm. F can not be entirely ruled out on the basis of evidence already presented. This possibility, however, seems rather remote as far as this country is concerned, for it is well known that in the United States people have been using, for as long as forty years, waters whose fluoride concentrations were considerably higher and no known pathological effects, other than on the teeth, have been reported.

Assuming that properly planned and conducted studies demonstrate the harmlessness of long continued use of waters of considerably higher [14] fluoride concentration than 1 ppm. for effects other than teeth, it would seem that the next step would be a practical test of this hypothesis utilizing human populations. Two cities in the 40,000 to 50,000 population range obtaining fluoride-free water from the same source would be most desirable. A rigidly controlled study, in which the fluoride concentration of one city's water was brought up to 1 ppm. and the population of both cities born subsequent to the change kept under observation for a sufficient number of years would be necessary to demonstrate that the addition of that amount of fluoride to a fluoride-free water will actually reduce the amount of dental caries in the community.

Should this crucial experiment prove successful, and an unusual amount of

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[14] Amarillo, Tex. and Colorado Springs, Colo. are examples of cities which have used relatively high fluoride waters for many years. The latter city has probably been using a water containing about 2.5 ppm. of F for at least fifty years. The Amarillo, Tex. water which has been in use for many years is considerably higher. It is well to emphasize, though, that in this country no detailed controlled epidemiological studies have as yet been made of populations such as Colorado Springs or Amarillo for the purpose of determining whether or not there are general systemic effects other than dental associated with the continued use of fluoride waters of these concentrations.

presumptive evidence so indicates, domestic waters from the standpoint of the relation of fluoride to dental health would hereafter be classified into three groups:

(1) Those carrying naturally the *optimal* concentration of F, i.e., about 1.0 ppm., and would therefore require no treatment;

(2) Those carrying an *excessive* concentration of F requiring the removal of the excess in order to protect the community against endemic dental fluorosis (mottled enamel); or,

(3) Those *deficient* in fluoride, to which fluoride might be added to bring its concentration up to the optimal in order to inhibit dental caries attack.

Viewing the domestic water problem in this light, one might with justification expect that the community's public water supply is destined to play an important role in the communal dental health.

In closing, it is well to emphasize again that the conversion of this observed natural phenomenon into one of general usefulness necessarily requires that specifically planned epidemiological studies clearly demonstrate the safety of low fluorination as it might relate to other aspects of the community's general health.

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Discussion

R. F. Goudey *

The suggestions that the fluoride content of water supplies be fortified to 1 ppm. as a means of reducing caries is not fully sound. Water supply is only a minor source of fluoride to the human system. Food substances contain up to 26 ppm. fluoride for 63 plant products.† Milk supply is another important source of fluoride.‡ It has also been demonstrated that milk and food are deficient in fluoride only when produced in areas where the water supply is also low in fluoride. There are many areas where milk supplies and food supplies are rich in fluoride, while the water supply in such areas is low. It follows, therefore, that the fluoride input whether from water, milk, or food should be the basis of control rather than fortification of water alone. It is also reasonable to expect that in some instances where milk and food are high in fluoride but water is low that the addition of 1 ppm. of fluoride to the water might cause a total body input sufficiently high to cause mottled enamel. It is therefore suggested that water supply officials refrain from acceding to the suggestion that fluoride content of the water supplies be juggled on the basis of present information.

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† Analyses show average of over 5 ppm. for F in 32 edible food substances and 26 ppm. for 63 plant products with more in leaves and skin than stems and pulp. (*See* NICHOLS, M. STARR. Occurrence, Pathological Aspects and Treatment of Fluoride in Water. Am. J. Pub. Health, **29**: 996 (1939).

‡ Cox says: "Reduction of dental caries through such media as bottled water, milk supply and fluoride containing medicinals are feasible—control of fluoride in whole dietary of children should be undertaken. (*See* SMITH, M. C. & SMITH, H. V. Observations on the Durability of Mottled Teeth. Am. J. Pub. Health, **30**: 1050 (1940).

Author's Closure

The general theme of Mr. Goudey's discussion, the quantitative aspects of fluoride intake, is highly important and constitutes an integral part of the whole question of fluorine and dental health. As such it has received serious consideration although much additional study remains. A paper discussing aspects of fluoride intake entitled: "Fluoride Ingestion and Dental Caries—quantitative relations based on food and water requirements of children one to twelve years old" by Senior Biochemist Frank J. McClure, USPHS, should clarify some of the points raised. This paper has been accepted for publication in the American Journal of Diseases of Children and should appear shortly.

The quotation in Mr. Goudey's discussion: "Food substances contain up to 26 ppm. of fluoride for 63 plant products" is taken from an article in the Sept. 1939 issue of the Am. J. Pub. Health which quotes from a *review* article by Frank J. McClure in the Physiological Reviews of 1933, which in turn quoted figures published by Gautier and Clausman in 1916.

Improvements in the methods for the determination of fluoride indicate that these old figures are unusually high and presumably erroneous.

As McClure states in his forthcoming paper, "Most foods appear to contain somewhat less than 1.0 ppm. of

fluorine in dry substance. Although fish foods and teas may contain on the average as much as 8 ppm. to 12 ppm. and 30 to 60 ppm. of fluorine respectively, these foods do not usually occur in appreciable quantities in children's diet."

Table 5, in the McClure paper, which is to appear in the Am. J. Dis. Child. is of interest:

Mr. Goudey also states that the "milk supply is another important source of fluoride." Actually the normal fluoride content in cow's milk has been found to vary between rather narrow limits generally in the neighborhood of 0.1–0.2 ppm. of F. These fluoride levels are not appreciably influenced even when the cattle are fed relatively high fluoride containing supplements. Furthermore the recent work of MacIntire and his associates indicates that the use of a high fluoride fertilizer does not increase the fluoride content of forage crops grown thereon to any appreciable degree.

[TABLE 5]

*Fluoride Content of Foods as Reported in the Literature**

Food	Fluoride (ppm.)	Food	Fluoride (ppm.)
Fluoride Reported in Food as Consumed			
milk	.07– .22	pork	<.20
egg white	.00– .60	pork chop	1.00
egg yolk	.40–2.00	frankfurters	1.70
butter	1.50	round steak	1.30
cheese	1.60	oysters	1.50
beef	<.20	herring (smoked)	3.50
liver	1.50–1.60	canned shrimp	4.40
veal	.20	canned sardines	7.30–12.50
mutton	<.20	canned salmon	8.50– 9.00
chicken	1.40	fresh fish	1.60– 7.00
		canned mackerel	26.89†
Fluoride Reported in Dry Substance of Food			
rice	<1.00	honey	1.00
corn	<1.00	cocoa	0.50–2.00
corn (canned)	< .20	milk chocolate	0.50–2.00
oats	1.30	chocolate (plain)	.50
crushed oats	< .20	tea (various brands)	30.00–60.00
dried beans	.20	cabbage	.31– .50
whole buckwheat	1.70	lettuce	.60– .80
wheat bran	<1.00	spinach	1.00
whole wheat flour	1.30	tomatoes	.60– .90
biscuit flour	0.00	turnips	<.20
flour	1.10–1.20	carrots	<.20
white bread	1.00	potato (white)	<.20
ginger biscuits	2.00	potato (sweet)	<.20
rye bread	5.30	apples	.80
gelatin	0.00	pineapple (canned)	.00
glucose	0.50	orange	.22

* For the source of these analytical data see reference (15) McClure, F. J. National Inst. of Health Bul. No. 172 (1939).

† See Ref. 25.

The discussion states: "It follows, therefore, that the fluoride input whether from water, milk, or food should be the basis of control rather than fortification of water alone." We are in complete agreement with the general concept, namely, that the entire fluoride intake must be considered. And should areas be brought to light where the fluoride intake through food and milk is sufficient to supply the optimal fluoride intake, it would be not only useless but actually harmful to add fluoride to a fluoride free water. But as a matter of epidemiological interest, where are these areas in the United States where the milk and food supplies are sufficiently high in fluoride to compensate for a fluoride free domestic water?

The calcifying permanent teeth are very sensitive indicators of fluoride intake, and an analysis of epidemiological data indicates that endemic dental fluorosis in this country is almost invariably a water-borne disease. While it is true there may be sporadic instances of cases diagnosed as "very mild" in a community which seemingly can not be attributed to the water supply, the percentage incidence of such cases is negligible. For example, a few years ago we made a careful examination of 2042 white public school children (Waukegan, Evanston, Oak Park, Ill.; Michigan City, Ind., and Escanaba, Mich.) whose histories indicated continuous use of the fluoride-free Lake Michigan water. Among these 2042 children were twelve, or 0.6 of one per cent diagnosed as "very mild" dental fluorosis; none were diagnosed as "mild," "moderate" or "severe." It would appear that at least in these five cities the *fluoride intake from sources other than domestic water* was insufficient to produce even the very faintest signs of dental fluorosis in as little as one per cent of the group.

Mr. Goudey's very pertinent discussion deals with a highly important facet of this problem and emphasizes one of my closing sentences: "Much investigative work, however, is necessary before serious thought can be given to a recommendation for its general application."

The Public Health Significance of Dental Deficiencies

By Harold J. Knapp

THE first aim of medicine and of public health officers should be the prevention of disease and the second, the prevention of, or at least the lessening of, incapacity from disease.

To accept this subject, "The Public Health Significance of Dental Deficiencies," is to take on a very large order. As health officer of this city, the speaker must confess to very specific limitations in the field of dental hygiene.

So many persons think of the health officer as an annoying person who appears with hammer and tacks, and posts a notice of contagious disease on one's front door. While it is true that much effort must be directed toward the control of communicable disease, this duty is only one, although an important part of a modern generalized public health program.

Nor must we forget that there are many influences that bear either favorably or unfavorably upon the health of the residents of city, county, state, or nation. Let us also reflect that disease recognizes no geographical borders and that even the social conditions of one state may extend into another. Water and milk supplies, transportation facilities, conditions of sanitation, concentration of population, race, climate, altitude, prosperity, plagues, panics, drouths, floods—these are some of the conditions that have either direct or indirect bearing upon health.

I wish to point out that it is not always easy to evaluate the need for certain public health programs nor to be too sure in pointing with pride to accomplishment in the fight against morbidity and mortality. Our results are too often intangible and not easily measured. How are we to demonstrate for instance, the number of cases of a given communicable disease prevented by having found and quarantined one case? Comparative morbidity and mortality rates do not always portray the complete picture.

In planning health activities, the interest and attitude of various professional groups and lay agencies must be gauged. With their sympathy and support much can be accomplished; without them, little.

I am put to it to define "dental deficiency" but am inclined to classify it as a symptom or result of some other condition rather than a distinct entity. It would appear that, if dental deficiency exists, something has caused it. In medical practice, the wise physician must diagnose before he prescribes treatment and he cannot diagnose until he is in possession of all of the facts that can be gleaned.

A paper presented on June 17, 1943, at the Cleveland Conference, by Harold J. Knapp, M.D., Commissioner of Health, City of Cleveland, O.

In the promotion of the public health, the epidemiological approach to a particular disease control problem is all-important. No community may expect to adequately control a disease without exact knowledge of when, where, and under what conditions it occurs.

Dental Deficiency Studies in Cleveland

For many years Cleveland has been conscious of the problem of dental deficiencies and an extensive local study has been made of the problem. Reference is made to "An Analysis of Half A Million Examinations of Sixth-Year Molars," compiled by Howard Whipple Green from data supplied by the distinguished pioneer in this field, the late Dr. Harris R. C. Wilson, Supervisor of Mouth Hygiene, of the Cleveland public and parochial schools (1). This statistical study was completed in 1935. While the Green study contains an enormous amount of information about dental conditions of Cleveland school children, it will be obvious that the findings apply only to Cleveland children and may not parallel too closely conditions in other cities of radically different geographical situation, climatic condition, or racial tincture.

I shall not bore you with a recital of statistics excepting to state that we do know, for instance, that dental caries exists, in greater or lesser degree, in about 80 per cent (2) of all Cleveland grade school children. We also know that there is a difference of susceptibility in different races and even in the same race (1). Our negro children, especially those southern-born manifest the least dental caries.

The Green study and the activity of several civic groups have resulted in the establishment in 1941, of two large dental filling clinics for indigent children in public schools strategically located. The operation of these clinics is under the joint direction of the Division of Health and the Board of Education, with financial assistance from the Cleveland Welfare Federation.

The nomination of the professional staff and consultation relative to the maintenance of professional standards, is provided by the local dental society through a representative Dental Advisory Committee to the Commissioner of Health. These clinics thus supplement the educational and case-finding program of public and parochial schools. Emphasis is placed upon preservation of the sixth-year molar teeth. I must admit, however, that to date our local efforts at control have been largely directed toward the early detection of caries and the minimizing of its ravages.

Character of Dental Deficiency

I am impressed by the several scholarly contributions of Dr. Dean (page 1161 herein) and his co-workers (3) on the significance of fluorides in water, in the prevention of dental caries. The evidence presented is both impressive and convincing. These scientists are to be commended for their epidemiological approach to this problem of preventive dentistry. Always intriguing to the health officer is the mass approach to the control of diseases. The contribution of the public health engineer in the purification of public water supplies, thereby eliminating the hazards of typhoid and water-borne diseases, is a notable example of the mass approach method.

But allow me to conjecture a bit concerning so-called "Dental Deficiencies." Perhaps one type results from inade-

quate care and feeding and medication of the expectant mother of the person in whom it manifests itself in later years. If so, it becomes a public health problem and the concern of health officials, thus stimulating the need for, and the provision of, better prenatal care for all expectant mothers. A well-conducted prenatal program for example, may ferret out syphilis in the pregnant woman and through intensive treatment forestall a definite dental defect in her offspring.

Does dental deficiency arise as a result of neglect of the proper feeding of our infants? If so, it again devolves upon us as health educators to teach the value of breast feeding, to attempt to convince parents of the necessity for keeping in contact with their physician for his advice, and to provide infant welfare services for well babies where their diets may be supervised—diets that include full vitamin coverage.

May dental deficiency be due to a lack of sunshine and fresh air, conditions such as prevail in the squalor of tenements and other overcrowded living-quarters? If so, one more public health argument is furnished for the detection of deplorable housing conditions and the bringing about of their correction.

If dental deficiencies are one result of poverty with its undernutrition, intensified assistance to deserving families in securing reasonable dietaries is indicated.

Is it probable that dental deficiencies may result from acute infectious disease? Some research observers have pointed to the dental damage done by an acute infection. If infectious disease is an important factor, our obligations in the prevention and control of communicable disease become increasingly apparent. This means a continuing search for early cases, and intensive investigation of their contacts.

Do major dental deficiencies develop from minor ones? Then we must establish means of identifying the early dental defect in the infant and young child and to provide facilities, if possible, for arresting the progress of such defects to forestall the development in later life of a major health hazard to that individual.

Are dental deficiencies primarily the result of a lack of some substance in the community drinking water or in commonly used foods or accessories? If this is proved to be true, should not that lack be supplied? The correlation of the incidence of caries and fluorides ingested has been emphasized by Doctors Dean, Ast (pages 1161, 1191 herein), and other workers (3).

Co-operation for Control

It has been my purpose to ask these hypothetical questions and to answer them with the condition "if that be so." This approach seems rational because of the apparent multiplicity of dental deficiencies as previously listed; and relatively little that has been scientifically settled concerning either their cause or their remedy.

From the public health viewpoint, a dental deficiency control effort is time well invested, since follow-up investigation may often reveal other incipient disease previously unsuspected in the persons of other members of the family or conditions prejudicial to the home or neighborhood. As an example, many a case of early tuberculosis in some other member of the family has been discovered by the alert public health nurse, even though her primary mission had been directed at a radically different problem.

Again, while as health workers we strive to avert the end results of dental deficiency, we often enhance the general health, since such conditions cannot adversely affect teeth alone—they are apt to exert a deleterious influence upon the whole human economy. The teeth comprise but one, although very finely and delicately constructed, of a marvelous combination of organs which together form the human body. With one out of gear, the whole machine slows down, if it does not stop altogether.

In any public health program, it is necessary that the several scientific professions concerned be recognized and that each play its role in a co-operative endeavor. One cannot be a specialist in all things, and should not be a jack-of-all-trades. The objective of public health officers is the prevention of disease and the elimination of conditions that conduce to the occurrence of disease. The actual practice of medicine and dentistry belongs in the hands of medical and dental professions, and in them we must repose full confidence. Likewise, we rely upon the public health engineer to lead the way and to provide the best engineering practice.

It is fitting that a testimonial be expressed to the imagination, the vision, and the courage of the engineering profession. Through the years it has blazoned many a trail in public health. Certainly without its ingenuity and its continuing research, and its technical skill, we should not now enjoy the benefits of the modern methods and appliances which protect us from disease. Would it not be tragic to be compelled to lapse back to the primitive conditions of yesteryear?

It is our official duty as health officers (and certainly it is our personal desire) to be alert to the research and to the progress in applied engineering practice; to the end that we shall neither be the first to reject nor the last to accept.

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A Program of Treatment of Public Water Supply to Correct Fluoride Deficiency

By David B. Ast

DENTAL caries has affected mankind from time immemorial. As far back as one can search in history, references are made to tooth morbidity and tooth mortality. Through the last century, marked progress has been made in the technical aspects of restorative dentistry, but very little progress has been made in preventing the onset of dental caries. In spite of the advances in operative and prosthetic dentistry, less than 25 per cent of the people receive anything like adequate dental care, while practically the entire population is in need of this service. There is quite a wide disparity between yearly increments of dental defects and the number of dental corrections completed (1). Thus we are faced with a cumulative disease which is almost universal, without regard to age, sex, race or economic status, and a method of treatment which, up to the present time, seems wholly inadequate.

Because the entire picture of the etiology of dental caries is not very clear, it is argued that the disease cannot be prevented. It is almost axiomatic in medicine to say that in order to prevent a disease one must first know the cause. Beginning with the investigations of Black and McKay (2) in 1916, a good deal of evidence has been presented which seems to indicate that the presence of fluorides, within certain limits, in water supplies establishes a degree of immunity to dental caries in proportion to the concentration of the fluoride ingested during the years of tooth development. However, concentrations beyond 1 ppm. F may produce mottling of the enamel. The brilliant epidemiologic studies of Dean and his co-workers (3, 4), and the work of other investigators in the field and in the laboratories (5–7), leave little room for doubt concerning the correlation of the diminished incidence of caries and fluorides ingested. With such evidence before us, the potential advantage of reducing the incidence of dental caries by controlled, judicious use of non-toxic concentrations of fluorides added to potable water supplies seems worthy of further study. According to the drinking water standards adopted by the United States Public Health Service in 1942 (8), the permissible concentration of fluoride is 1.0 ppm. If it can be determined that this concentration or slightly less renders a fair degree of immunity to den-

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A paper presented on June 17, 1943, at the Cleveland Conference by David B. Ast, D.D.S., M.P.H., Asst. Director for Oral Hygiene, Division of Maternity, Infancy and Child Hygiene, New York State Dept. of Health, Albany, N. Y.

tal caries, health officials will have an opportunity of controlling this disease in a most effective and simple manner, because the individual will not be responsible for administration of the therapeutic agent.

With this in mind, it is proposed to set up a study in two cities in New York State, which, for purposes of identification in this paper, we shall call City A and City B. The purpose of the study is to determine the efficacy and the practicability of increasing the fluoride content of the potable water of City A to within the limits of 0.8–1.0 ppm. F, using City B, with water containing a negligible amount of F (0.05 ppm.), as a control. This study is planned on the premise that fluorine, in order to be effective, must be ingested during the years of tooth development, i.e., up to and including age 14 (excluding the third molar), and that the subject must be continuously exposed to the fluoride-contained drinking water throughout this period. It will therefore take about 10 to 12 years to determine the value of such a procedure with periodic dental examinations of all children from the time of tooth eruption through age 14.

The Study

City A and City B are approximately 30 miles apart, and each has a population of about 30,000, with a 5- to 14-year old group of about 4200. This size population is desirable from a statistical point of view because Dean (9) has estimated that at the end of ten years about 65 per cent of the original study group will have moved away or presented such discontinuities of exposure to the fluoride that they will have to be excluded from the study. It is to be noted that discontinuity of

TABLE 1

*Analysis of Population for Cities A and B**

Age Groups	All Classes			Native White		Foreign-Born White		Colored†	
	Total	Male	Female	No.	%	No.	%	No.	%
City A									
Under 5	1,885	954	931	1,772	94	4	0.2	109	6
5–14	4,425	2,220	2,205	4,179	94	23	0.5	223	5
15–19	2,538	1,258	1,280	2,393	94	55	2	90	4
20–34	7,923	3,903	4,020	7,287	92	357	4	279	4
35–44	4,681	2,322	2,359	3,799	81	690	15	192	4
45 and over	10,431	4,938	5,493	7,484	72	2,693	26	254	2
Total	31,883	15,595	16,288	26,914	84	3,822	12	1,147	4
City B									
Under 5	1,810	919	891	1,731	95	2	0.1	77	4
5–14	4,126	2,083	2,043	3,982	96	15	0.3	129	3
15–19	2,278	1,104	1,174	2,190	96	28	1	60	2
20–34	6,542	3,148	3,394	6,139	93	209	3	194	3
35–44	4,125	2,030	2,095	3,579	86	377	9	169	4
45 and over	9,708	4,385	5,323	7,929	81	1,549	16	230	2
Total	28,589	13,669	14,920	25,550	89	2,180	7	859	3

* Federal Census, 1940.

† Predominantly Negro.

exposure to fluoride treated water up to 30 days in any one year is permitted. The population groups are fairly similar as to race and economic status (*see* Table 1).

The analysis for fluoride was made by the Scott modification of the Sanchis method (10).

Since the water supply of City A is the one which is to be treated, a brief description of the source of its water, the filtration plant and its personnel is pertinent to the study. A comparison of the water supplies of the two cities is given in Table 2.

TABLE 2

A Comparison of Water in City A and City B

	City A, at Clear Well Effluent	City B, at Filter Plant—Filtered
Color	0	5 ppm.
Turbidity	Trace	5 "
Free NH_3	0.006 ppm.	0.004 "
Albuminoid NH_3	0.104 "	0.148 "
Nitrite	0.001 "	0.001 "
Nitrate	0.02 "	0.06 "
Oxygen Consumed	2.4 "	1.3 "
Iron	0.03 "	0.2 "
Chlorides	4.6 "	1.4 "
Hardness	74 "	20 "
Alkalinity	46 "	11 "
Fluoride	0.12 "	0.05 "
pH	7.8 "	6.8 "

The water supply of City A is secured from two impounding reservoirs having capacities of 1200 and 350 mil.gal., located 2½ and 4 miles from the city. These reservoirs drain an occupied water shed of 6.8 sq.mi., populated by some 200 people. Approximately 25 per cent of this area is owned by the city and about 1000 acres of the city property is fenced. The supply is protected by rules and regulations enacted in accordance with the provisions of Section 71 of Article V of the Public Health Law of New York State.

The plant has a capacity of 5 mgd. and actually operates at rates varying from 2.5 to 3.5 mgd., except during periods of very serious fire, when rates as high as 7.0 mgd. have prevailed for a few hours.

The raw water flowing to the filtration plant is coagulated with alum and is mixed for a period of approximately 10 minutes by aeration and agitation incidental to flowing around baffles. The alum dose is usually ¾ to 1 gpg., although somewhat higher alum doses are used for short periods of time.

The raw water also is subject to pre-chlorination with a usual dose of 12 lb. per mil-gal., or approximately 1.5 ppm. Carbon to the extent of about 35 lb. per mil-gal. also is applied to the raw water for taste and odor control.

Pre-chlorination of the water is sufficient to provide a concentration of residual chlorine of approximately 0.4 ppm. after the water has passed through the sedimentation basin during a period of 3½ to 4 hr.

The filtration plant consists of four filters of 1.25-mgd. normal rate. Filter runs as high as 50 hr. are normally experienced following effective coagulation and sedimentation of relatively clear water from the impounding reservoirs.

The filter effluent is chlorinated with a small chlorine dose of about 1.25 lb. per mil.gal. which, following pre-chlorination, is sufficient to produce a residual of 0.25 ppm.

Hydrated lime, in the amount of about 85 lb. per mil.gal., is added to the filtered water for corrosion prevention so as to provide usually a final pH of about 8.3.

A covered filtered water reservoir of 200,000-gal. capacity is located adja-

cent to the filtration plant. Water flows by gravity from this clear well to a portion of the city and the high-level portion of the city is supplied by a booster pumping station.

This filtration plant is under the supervision of a Grade I operator who is a technically trained chemist and who is assisted by three operators, a janitor and a laboratory technician.

The plant has 5 dry feed units. Three of these units are in constant use, applying lime, alum and activated carbon. One is available for applying activated carbon directly to the filter influent if need should arise. One therefore would be available for the application of sodium fluoride. These units are reliable and sufficiently accurate for the purpose.

The procedure is to operate the filters at their normal designed rate and to use two or more in accordance with the demands in the city. This means that the rate of filtration would be 2.5 mgd., 3.75 mgd. or 5.0 mgd., depending upon whether 2, 3 or 4 filters were used. Rates in excess of 5.0 mgd. during periods of emergency are secured by adjusting each rate controller. The important point is that these changes in the filter rate can be anticipated and corresponding changes are made manually in the chemical feeders.

Addition of Sodium Fluoride

The average consumption of water in City A is about 2.85 mgd. If the amount of wash water be added to this amount, the total amount of the water to be treated is approximately 3 mgd.

In order to obtain a concentration of 0.8–1 ppm. fluoride in the tap water, 1.77 ppm. sodium fluoride will have to be added to the filtered water. It should be added to the filtered water because alum coagulation may lead to partial removal of the sodium fluoride. The dosage of 1.77 ppm. sodium fluoride is equivalent to 14.6 lb. per mil.gal. of water treated. This will necessitate adding 43.8 lb. of sodium fluoride per day to the filtered water. This can be added in measured amounts to the water supply through the use of dry feed equipment now in use at the plant. Chemical dosing equipment used at filtration plants is accurate to within 5 to 15 per cent of the intended dose. Overdoses therefore would be due primarily to error in judgment on the part of the operator rather than to mechanical reasons. However, mechanical difficulties would generally lead to a reduction in the dose or the stoppage in the application of the chemicals. Accidental overdosage, even deliberate, which might be of a serious nature, seems unlikely.

The average daily per capita (adult) consumption of water for potable purposes is approximately 2600 ml. (11). This is made up of about 1450 ml. of potable water, 800 ml. of water from food and milk and 350 ml. generated through the oxidation of hydrogen in the body. Inasmuch as a portion of the water in food will be that added in the cooking process, the food so prepared will contain an equivalent amount of any fluoride present in the water supply. Therefore the consumption from the public water supply system is likely to be approximately 2 l. per day. The lethal dose of sodium fluoride is about 4 g. (12), which would necessitate having 4000 mg. of sodium fluoride in the 2 l. of water consumed by an individual in one day. Therefore the water would have to contain 2000 mg. sodium fluoride per liter, or 2000 ppm. sodium fluoride. This concentration represents a dose of 16,600 lb.

per mil.gal., which, for City A, would mean about 25 tons of sodium fluoride added to the water supply in a day. The sub-lethal dose is about 230 mg. (12) sodium fluoride which would require adding 2,847 lb. sodium fluoride in a day. These very large amounts are well beyond the capacity of small chemical dosing equipment suitable for applying an average dose of 44 lb. per day.

By adding 1.77 ppm. sodium fluoride (0.8 ppm. fluorine) the individual would ingest 3.54 mg. sodium fluoride (1.6 mg. fluorine) in the 2 l. of water he would drink daily. This, of course, is the important consideration. If the concentration used in this study proves adequate to reduce appreciably the incidence of dental caries then, in such places as the south, where due to excessive heat more water is imbibed daily, the concentration of fluorine may be diminished so that the amount ingested runs from 1.6 to 2.0 mg. per day.

Determination of fluoride content will be from tap water samples and will be made according to procedures developed and published by a Committee of the American Water Works Association (10). Samples will be checked weekly; however, it may be determined after the study has been under way for some time that monthly examinations may be sufficient.

An analysis of commercial sodium fluoride shows:

	per cent
Sodium Fluoride—NaF	95.20
Sodium Chloride—NaCl	0.25
Sodium Bicarbonate—$NaHCO_3$	0.25
Sodium Carbonate—Na_2CO_3	0.50
Sodium Silicofluoride—Na_2SiF_6	1.8
Sodium Sulfate—Na_2SO_4	2.0
Arsenic—As_2O_3	0.0002
Density—95 per cent (light)	60 lb./cu.ft.
95 per cent (dense)	76 lb./cu.ft.

Sodium fluoride comes packed in barrels containing 375 lb. net and in kegs containing 125 lb. net. While the price fluctuates, the last price list from one of the larger chemical companies was $7.75 per 100 lb. in 10-bbl. lots and over. For the treatment of water in City A, about 8 tons would be required for a year, which would cost about $1200–1300.

Examination of All School Children, 5–14 Years Old

A dental examination, with mouth mirror and sharp explorer, of all children aged 5–14 (age to be defined by last birthday) in both City A and City B is planned at the outset of the study. Examinations are to be repeated annually and it is desirable that the same examiner be used. There may be a wide variation between different dentists in diagnosing small carious lesions, especially pits and fissures. These examinations will be made in the schools.

Bacteriologic examinations for *L. acidophilus* in the saliva of the children under study will be taken periodically. These findings may be useful to serve as an index of caries activity. Jay has demonstrated a correlation of high counts of *L. acidophilus* and active caries (13). Other investigators have made similar observations (14, 15).

For purposes of this study, the caries experience of the children examined will be recorded on a chart similar to the one used by the U.S.P.H.S. in its Illinois study in 1941 (4). This will permit recording, in addition to the general history of the patient, the past and current caries experience of the primary as well as the permanent teeth, the *L. acidophilus* counts and a suffi-

cient history to determine the continuity of exposure to the public water supply. The card is also adapted for punch card machine analysis.

The data from these records should provide the following information: (a) caries experience for the various age groups and by sex (age being defined as last birthday); (b) yearly increments of dental defects for the various groups by age and by sex; (c) *L. acidophilus* counts in relation to caries activity; and (d) signs of mottled enamel, if any.

New Personnel

Two senior dentists will be appointed to make dental examinations for approximately 8500 children in Cities A and B. Also, there will be two clerks, to record histories and results of dental examinations.

It takes about 10 min. for each examination, so that for the above mentioned group, two dentists will have about 20 weeks of work each. The balance of their time may be used in the oral hygiene program of the Department. The clerks may be employed on a part-time or temporary basis. No additional personnel will be necessary at the filtration plant.

Annual Budget

Personal service:		
2 Senior dentists (half time) @$1560 each . . .	$3120	
2 Clerks (part-time, 6 mo. each) @$100 per month	1200	
		$4320
Supplies:		
16,000 lb. NaF @$7.75 per 100 lb.	$1240	
Record cards (10,000) . .	300	1540
Total		$5860

Problems Involved

1. Public psychology is, in the author's opinion, the most difficult obstacle to overcome. A community priding itself on its clear, cold water supply may be very reluctant about having anything added to it, especially so when the agent to be added has had wide publicity as an insecticide and a potent poison. It will therefore be necessary to "sell" the idea to the community through a well considered presentation of the facts, of evidence, cost, safety of the concentration of the agent to be used and ease of dosage control, also the benefits likely to accrue to the present generation of young children and the coming generations. The cooperation of key physicians, dentists, public spirited citizens and city officials is highly desirable. It is very important to avoid public discussion of the project before the plan has been "sold" to the key citizens.

2. Questions of toxicity will have to be answered frequently. While the literature on chronic and acute fluoride toxicosis is not too well defined, all reports indicate concentrations far in excess of that suggested in this study (12, 16, 17).

3. Problems of administration are not numerous or difficult, once the project has been accepted by the community. Supervision of the dental clinicians periodically is desirable and frequent checking of the services of the clerks is necessary. It is also desirable to have the State laboratory make periodic analysis to check on the findings at the filtration plant.

Conclusion

It has been demonstrated that dental defects are the most prevalent defects to which our people are subject. While dentistry has made great strides dur-

ing the past century, the present methods of controlling dental caries have not proved adequate. The New York State Department of Health, fully cognizant of the extent of the dental problem, its public health significance and the need for a more satisfactory method of controlling dental caries, has approved the study embodied in this paper. If this study proves to be practicable and effective, dentistry and public health may achieve a victory comparable with the control of many infectious diseases by immunization today.

The author is grateful to C. R. Cox, Chief, Bureau of Water Supply, Div. of Sanitation, New York State Dept. of Health, for his advice and counsel in planning this study.

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What Are the Responsibilities of Public Water Supply Officials in the Correction of Dental Deficiencies

By Abel Wolman

THE situations presented to you by Dr. Dean (p. 1161) are staggering in their possibilities for the future, particularly with reference to the water works officials' contribution to them. If I may rephrase two or three of the general assumptions, which are almost in the nature of conclusions by Dr. Dean, they are of this character:

First, that the current evidence seems to indicate that a small amount of fluorine contributes to a high level of dental health.

Second, that this conclusion is of long historical standing.

Third, that there are sound reasons and sound hopes to attempt to solve an almost insoluble situation by the mass handling of dental caries, which so far has not succumbed successfully to individual patient treatment.

Need for Co-operation

Our first reaction, to which Dr. Knapp has already referred (p. 1187), is one which we should avoid, i.e., to reject a proposal for using the public water supply as a medium for correcting a defect in this field, without careful review of all the relevant facts.

We tend to forget that we are producing day by day a highly variable material which we feed to the community, differing from area to area, from time to time, and from relationship to relationship as the art advances.

It is well to recall, therefore, when we are diagnosing this potentiality of responsibility that it was not so many years ago when we went through severe medical, engineering, and legal controversy concerning the addition of alum to water, for the purpose not of adding a useful ingredient, but of subtracting a series of objectionable ingredients. You will recall that when that was done in the early days—and the not so very early days at that, we went through a long series of battles of the most acrimonious and expensive types in order to assure ourselves and the public that the physiological results of what we were attempting to do were less important than the accomplishments we hoped to make.

You likewise will recall that that experience was paralleled when we first began the addition of chlorine in its hypochlorite form and later in the liquid chlorine form. There, too, we had an amazing set of controversies which ran through the courts, through most of the medical associations, and all of the engineering associations, in order

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A paper presented on June 17, 1943, at the Cleveland Conference by Abel Wolman, Dr.Eng., Prof. of San. Eng., Johns Hopkins University, Baltimore, Md.

to prove again that the balance of values was in favor of, and not against the public, even though there was raised then, as now, the interesting question as to the physiological effect of chlorine. It is still raised in a good many communities even before the chlorine unit is installed. But in every case, fortunately for the public, the results have been advantageous as far as mass diagnostic tests permit us to make any diagnosis.

That whole history, however, covered the effort to eliminate products from water rather than to introduce new complexes of a chemical or biological nature.

Complexity of Situation

Curiously enough, within the last ten years we are modifying that in a subtle but important way, which administratively we must remember. We have now literally been pushed into the area where we are "tailor-making" the water supplies of this country. We are adding as well as subtracting materials, complexes and characteristics in order to meet a long and an ever-extending series of requirements on the part of the consuming public, whether for domestic or industrial use. In every one of these instances we naturally are caught as always between the upper millstone of the desire to adjust the material which we are producing to greater public value and the lower millstone of avoiding the danger to the consumers of any deleterious effects.

Now Dr. Dean and his group come along with a very much more complicated situation, to add to our troubles. It is important, however, to recall that it is a part of an evolutionary process. It is part of the attempt to process the water supply not only for the removal of material, for the gradual adjustment of that material for better use and, lastly, as a carrier for elements or complexes which would improve or raise the general level of the public health of the community.

In theory at least there is no reason why we should go three-quarters of the way and not the other quarter in the processing of the public water supply. I emphasize that *in theory* there is no reason. I am not ready to move toward any suggestion at the moment that *in practice* we need or should go all the way in the light of our present evidence.

Likewise, there is no outstanding reason why we should concentrate our efforts from the disease standpoint on only typhoid fever and the associated group of enteric diseases, which incidentally, of course, in comparison statistically with dental caries are quite unimportant. They are still, of course, of great significance in control, but statistically in numbers they have far less impact on the over-all community of this country than the group of diseases to which Dr. Dean has referred.

Since in theory we are accustomed to processing, to "tailor-making" public water supply for purposes of disease control, for purposes of industrial use, for purposes even of physiological adjustment, in theory again we should not bar automatically any suggestion which would make public water supply an improved medium for raising the general physiological level of the public. In practice, however, in this particular field I feel quite sure that Doctors Dean and Ast do not suggest that at this stage all of the low-fluorine waters of this country should be subjected to the addition of fluorides beginning the first of July. Dr. Dean's paper is a masterpiece of balanced cau-

tion with respect to the findings which he discloses and with respect to the influence which those findings should have on public water supply administration. He points out, however, that in the offing, in the future, perhaps, in the not-too-distant future, as the evidence accumulates on controlled areas, areas which are being expanded in number and in characteristics—as that controlled evidence is accumulated and if it continues to push forward the preliminary conclusions—then the water works profession must give careful consideration to the simple question with complex results: whether or not fluoride control should be part of the current armamentarium of water supply treatment.

Administrative Evaluation

It might be well to say a word here from the administrative standpoint. It may develop that there will be other suggestions and other uses of similar nature. I need hardly recall to you the use of table salt as a carrier of iodine as a preventive for goiter. The results with that have been not as good as were anticipated perhaps, 15 years ago. It is rather interesting that the use of salt for that purpose is declining. It is also true that the first experience of the use of a public water supply for the introduction of iodine was in Rochester where it did not last long, and for sound reasons. Blanket application of iodine, for the prevention of goiter was at the time considered by certain experts an unwise use of the public water supply.

The additive processing of flour to introduce certain desirable attributes for the general public welfare and health is now in the making. It is too early to say how that type of mass treatment would meet the problem of dietary deficiencies to the greatest advantage, but always the public health officer has been searching, and with reason, for a method of mass attack on almost every conceivable disease. It is the cheapest, simplest and most rapid way of handling the situation, if it is applicable.

I have sometimes been interested in rehearsing in my own mind how long it would have taken us to bring the typhoid fever death rate down to less than 5, much less to 1 per 100,000, if we had had to attack it on a piecemeal, individual basis throughout the United States. I venture to predict that it would have taken many, many centuries, even with the benefits of mass inoculation. It was only through the fortuitous advantage of a public water supply or milk supply that we were able to make such heroic reductions of that particular group of diseases.

I do not want to press these facts because I believe, as Dr. Dean does, I am quite sure, that this is not the day on which to press the water works operator to an acceptance of this proposal. It is, however, the day to press him toward an understanding of the reasons underlying the suggestion and to insist that in the intervening three, four and five years it must be taken to heart as a new proposal, perhaps as a new opportunity for service.

In closing, I am quoting one sentence from Dr. Dean's paper, which I think epitomizes any recommendation I may make to the water works official with respect to the addition of fluorides to waters for the reduction of dental caries. It is this: "Much investigative work is necessary before serious thought can be given to a recommendation for its general application." I do not think that I can add any more to that. If I did, I am afraid I would spoil it.

Rapid Tests of Water Quality

By F. W. Gilcreas

FIELD laboratory tests that can be performed quickly and with a minimum of equipment are essential for the control of the water supply treatment required to maintain safe sanitary quality under emergency as well as ordinary conditions.

Ortho-tolidine Test for Residual Chlorine

The ortho-tolidine test for residual chlorine is as adaptable for emergency testing as it is useful in the routine control of chlorination. Field kits containing permanent colored glass standards are in general use and provide for the elimination of interference by color and turbidity of the sample. Two-ounce French square bottles and liquid standards can also be employed, if care is taken to protect the standards from deterioration and from exposure to extremes of heat or cold and to replace them with sufficient frequency to prevent errors due to fading (1). Ortho-tolidine deteriorates on long storage and strong acid may extract from the rubber stoppers or plastic closures of the bottles coloring matter that affects the accurate reading of the test. The limitations of the determination have been widely discussed and improvements in the technic have been developed (2). For accurate results, the use of strong acid ortho-tolidine reagent and retention of the test portion in the dark during the 5-min. period for maximum color development are essential. The presence of manganese in the water under examination should be ascertained so that interference with precise determination of chlorine may be avoided.

Flash Test for Active Chlorine

The standard ortho-tolidine test measures chlorine present in the water as active chlorine, but, unfortunately, this measurement may also include chlorine combined with nitrogen or nitrogenous organic matter, i.e., chlorine of low bactericidal power. A modification designated as the "flash" test (3) depends upon the reaction of ortho-tolidine with free chlorine to produce immediately the characteristic yellow color proportional in depth to the concentration of chlorine in the sample. When a longer reaction time between the ortho-tolidine and the chlorinated sample is allowed, the chloramines or chlorine adsorption compounds may be decomposed; the chlorine thus set free will then react to

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produce the familiar yellow color. In carrying out the flash test, therefore, the immediate appearance of the yellow color indicates uncombined chlorine and any increase in the intensity of the color on standing, up to the 5-min. period designated as the standard technic, reveals the presence of these chlorine compounds. The color should first be observed after only 15 to 30 sec. of contact with ortho-tolidine. This can be accomplished if the ortho-tolidine is first dispensed in the bottle or cell and the sample added, thus providing for immediate mixing.

It is impossible to compare the color of the flash test with standards quickly enough for precise estimate of the amount of the free chlorine present. Recent studies, as yet not published, made in the laboratory of the New York State Department of Health propose a technic that will permit a quantitative estimation of the free chlorine distinct from that in combination with nitrogen or organic matter. If the value found with this test approaches that determined according to the standard ortho-tolidine technic, the presence of active chlorine is indicated. If the flash test value is less than 80 per cent of that obtained with the standard technic, chlorine compounds of less active disinfecting power than chlorine may be considered present. The flash test is most useful in the control of emergency chlorination, since complete bactericidal treatment must be attained even at the expense of excess dosage and production of taste or odor conditions.

Determination of High Chlorine Residuals

At times the maintenance of high residuals, greater than 1 ppm., may be essential for emergency treatment, particularly in the sterilization of contaminated mains or where excessive chlorination is required for some particular process. The standard (4, p. 21) ortho-tolidine technic will not measure residuals greater than 1 ppm.* The simplest procedure for that purpose at present is the "drop-dilution method" which has been described by Griffin and Chamberlin (5). In this test, ortho-tolidine is mixed with water of zero chlorine demand in a cell or 2-oz. French square bottle. One or more drops of the sample are added and if a distinct yellow color results, this is compared with standards and the residual chlorine value noted. If no color is obtained, the test must be repeated with increased volumes of the sample. If the volume of zero chlorine water and ortho-tolidine is 50 ml. and the addition of 1 ml. of sample produces a color equivalent to 0.5 ppm. of chlorine, this latter value multiplied by 50 will give the concentration of the chlorine in the sample—in this case, 25 ppm. This test is valuable also for emergency use in the field, and all water works operators should be familiar with it. No equipment other than that for the standard test is required.

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* EDITOR'S NOTE: The "Non-Standard Methods" section (Appendix I) of *Standard Methods* (4) includes (pp. 232–35) provisional methods for determining chlorine in excess of 1 ppm. The paper, "Colorimetric Determination of Chlorine Residuals up to 10 ppm. With Ortho-tolidine," by Chamberlin and Glass (*see* p. 1065 of the August JOURNAL for Part I and p. 1205 of this JOURNAL for Part II) outlines a method for determination of the higher chlorine residuals. This method is naturally not yet standard, but the use of the information contained in the paper is indicated when it is necessary to determine chlorine residuals of such a high density, when the analyst is technically satisfied with the data derived from it.

Determination of Chlorine Demand

The dosage of chlorine required for effective chlorination under emergency or routine conditions should be established. Thus, a test to determine the chlorine demand or the amount of chlorine that will be absorbed by the constituents of the water is essential. Probably the most satisfactory rapid tests are the qualitative and quantitative field tests described by Faber (6). The technics are simple and should be known by every water works operator. Only the equipment used in the routine ortho-tolidine determination is required.

In the qualitative test, 100 ml. of sample is treated with a drop of a standard sodium hypochlorite solution ("Zonite" may be used). This provides a dose of about 5 ppm. If, after a 10-min. contact, the reaction indicates the absence of free chlorine or only a trace, a chlorine demand of greater than 5 ppm., and thus serious contamination, is indicated. If a quantitative determination is desired, a sodium hypochlorite solution (Zonite) is first diluted to a definite concentration of chlorine. Precise amounts of this solution are then added to a 50-ml. or other known portion of the sample, providing an exact dosage of chlorine. The residual obtained in the test portion after a 10-min. contact is measured in the comparator.

Frequent determinations of the chlorine demand of the raw water are of great value in indicating a sudden or extensive increase in contamination. To interpret the results, data relative to the normal chlorine demand of the water, based on a long series of routine determinations on the untreated supply during times of minimum contamination, must be available. Any marked increase over this value, 1 ppm. or greater, indicates significant contamination, possibly resulting from floods or the discharge of sewage, industrial wastes or other types of contaminating substances into the source of the water. Thus, the need for further investigation of the quality of the supply is indicated, as well as the immediate necessity for increasing the application of chlorine and possibly other adjustments of treatment.

Determination of pH Value

The determination of the pH value, or hydrogen-ion concentration, of the water will not assist in the control of emergency treatment but will, if made routinely on the untreated supply, frequently reveal contamination, particularly by manufacturing wastes or other chemical compounds. The technic of this test is well known and relatively simple and can be carried out in the field using the "Hellige" test kit employed for residual chlorine determination plus the necessary color standards. Its inclusion with other rapid field tests, although not essential, is urged, in order that the additional information it furnishes may be available.

The water works superintendent or operator is responsible for the operation of his supply and for the maintenance of its safe sanitary quality. Not only is a thorough knowledge of the technics of various field laboratory tests necessary, but it is essential that their interpretation and value be thoroughly understood.

Rapid tests can be relied upon to give limited information but if more complete data concerning the type, the significance or the extent of contamination are needed, additional examinations must be undertaken either in a laboratory maintained by the water supply or in one where facilities for other

and more complicated determinations are available. The operator should find out where these services may be obtained, either through the county or other local laboratory or, if necessary, through the laboratory of the state department of health. Under existing war conditions, with shortages of trained personnel and with unusual potentialities for damage to equipment and contamination of water supplies, emergency analysis of the water may be required at any time. Local civilian protection organizations, particularly the mutual aid organization, should also be in a position to furnish information in regard to the location of the laboratory facilities required.

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Colorimetric Determination of Chlorine Residuals up to 10 ppm. With Ortho-tolidine

By N. S. Chamberlin and J. R. Glass

Part II—Modified Scott Permanent Chlorine Standards

THE results of a visual and spectrophotometric study of the ortho-tolidine-chlorine colors for residuals up to 10 ppm. were presented in Part I of this paper (1). In that report it was shown that, in order to prepare an accurate and reproducible set of temporary chlorine standards, a careful and laborious technique was required. It was also shown that these standards could be used for a period of only 30 min.

The need for a set of permanent standards is obvious. A practical set of permanent standards in place of the temporary standards should have the following characteristics:

1. Any standard of the set should be usable at all cell depths.
2. The stock solution should represent 10 ppm. chlorine and the standards representing all other residuals should be obtainable by proportional dilution of the 10-ppm. standard.
3. The standards should be composed of readily available materials.
4. Their preparation should not require special technique.
5. They should remain stable for approximately six months.

In aiming to attain such an ideal set of standards, the authors have been beset with many difficulties, some of which have not been overcome.

The Permanent Standards

The standards finally obtained after considerable investigational work by the authors are a modification of Scott's chromate-dichromate standards. Through modification, these standards conform closely in intensity and hue to the colors of the temporary chlorine standards prepared as described in Part I of this paper. Through this modification they meet most of the requirements for a practical set of permanent chlorine standards set forth above.

These new permanent chlorine standards, like the Scott standards, derive their color from quantities of chromate-dichromate in the presence of a buffer. The actual quantities of chromate-dichromate in the new standards, how-

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ever, differ from those in Scott's and the pH at which they are buffered is also slightly different. A phosphate buffer is used instead of boric acid-borate buffer as it has been found to be more effective.

The color intensity and hue of the standards is a function of both the amount of chromate-dichromate in the solution and the pH at which it is buffered. Since the temporary chlorine standards obey Beer's law up to only

TABLE 1

Modified Scott Permanent Chlorine Standards, 0.01 ppm. Cl to 1.0 ppm. Cl, for Cell Depths up to 300 mm.

Chlorine	Modified Scott Dilute Chromate-Dichromate*	Chlorine	Modified Scott Dilute Chromate-Dichromate*
ppm.	*ml.*	*ppm.*	*ml.*
0.01	1	0.35	35
0.02	2	0.40	40
0.05	5	0.45	45
0.07	7	0.50	50
0.10	10	0.60	60
0.15	15	0.70	70
0.20	20	0.80	80
0.25	25	0.90	90
0.30	30	1.00	100

* The volumes indicated above are pipeted into 100-ml. tubes of any uniform length and diameter or into 100-ml. volumetric flasks for use in bottles. The volume is then made up to the 100-ml. mark with the 0.1 *M* phosphate buffer, specified on page 1215.

1.5 ppm., the permanent chlorine standards can be maintained at a constant pH and proportional quantities of a buffered chromate-dichromate stock solution can be used for all residuals up to 1.5 ppm., each standard being good for all cell depths. The temporary chlorine standards deviate from Beer's law above 1.5 ppm.; therefore, an automatic shift of pH is accomplished by balancing the buffering effect of the chromate-dichromate against that of the phosphate buffer. In this manner it is possible to use proportional quantities of a buffered chromate-dichromate stock solution for chlorine residuals from 1.5 to 10 ppm. at one cell depth, and only slightly disproportional quantities at all other cell depths.

All the permanent standards are made from stock chromate-dichromate

TABLE 2

Modified Scott Permanent Chlorine Standards, 1.0 ppm. Cl to 10 ppm. Cl, for Cell Depths Indicated

Chlorine	Modified Scott Strong Chromate-Dichromate*			
	25–50 mm.	100 mm.	200 mm.	240–300 mm.
ppm.	*ml.*	*ml.*	*ml.*	*ml.*
1	10.0	10.0	10.0	10.0
1.5	15.0	15.0	15.0	15.0
2	19.5	19.5	19.7	20.0
3	27.0	27.5	29.0	30.0
4	34.5	35.0	39.0	40.0
5	42.0	43.0	48.0	50.0
6	49.0	51.0	58.0	60.0
7	56.5	59.0	68.0	70.0
8	64.0	67.0	77.5	80.0
9	72.0	75.5	87.0	90.0
10	80.0	84.0	97.0	100.0

* The volumes indicated above are pipeted into 100-ml. tubes of any uniform length and diameter or into 100-ml. volumetric flasks for use in bottles. The volume is then made up to the 100-ml. mark with the 0.1 *M* phosphate buffer, specified on page 1215. Standards for cell depths other than those given can be prepared by interpolating between the depths given. Standards for residuals other than those given may be prepared by interpolating between the residuals given.

solutions and are diluted, in accordance with Tables 1 and 2, with a standard buffer solution. This is a 0.1 *M* phosphate buffer solution and is made in accordance with the procedure given on page 1215.

A modified Scott strong chromate-dichromate solution, equivalent to 10

ppm. chlorine, is prepared by dissolving 4.65 g. potassium chromate (K_2CrO_4) and 1.55 g. potassium dichromate (K_2CrO_7) in 1 liter of the 0.1 *M* phosphate buffer.

A modified Scott dilute chromate-dichromate, equivalent to 1 ppm. chlorine, is prepared by dissolving 0.465 g. K_2CrO_4 and 0.155 g. $K_2Cr_2O_7$ in 1 liter of the 0.1 *M* phosphate buffer.

Temporary Standards *vs.* Existing Permanent Standards

In discussing two colored solutions it must be remembered that if they are spectrophotometric matches, they are certain to be visual matches at all cell depths and in all kinds of light. Under some circumstances colors can be visual matches even if their spectrophotometric curves are widely divergent. However, the more closely two solutions approach being spectrophotometric matches, the greater the variety of light conditions and cell depths they can tolerate and still be visual matches. Therefore, in matching the permanent standards with the temporary standards, an attempt was made to obtain as close spectrophotometric matches as practical, as well as visual matches under various light conditions by a number of observers.

To evaluate the Ellms and Hauser, the Muer and Hale and the Scott permanent chlorine standards in view of the new temporary chlorine standards, spectrophotometric curves were run on each of these. A few of them, chosen for comparison, appear in Fig. 1.

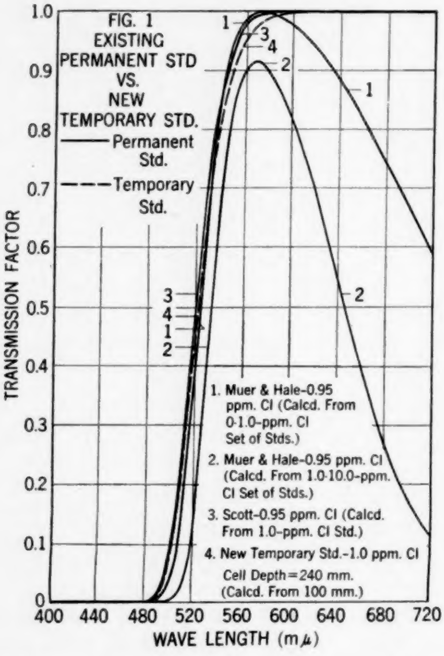
.The curves shown are for 240-mm. cell depth and are as follows: Curve 1, the Muer and Hale permanent standard for 0.95 ppm.* chlorine, calculated from the 0–1.0 ppm. set of standards (2); Curve 2, the Muer and Hale permanent standard for 0.95 ppm. chlorine, calculated from the 1.0–10.0 ppm. set of standards (2, 3); Curve 3, the Scott permanent standard for 0.95 ppm.; and Curve 4, the new temporary chlorine standard for 1.0 ppm. chlorine.

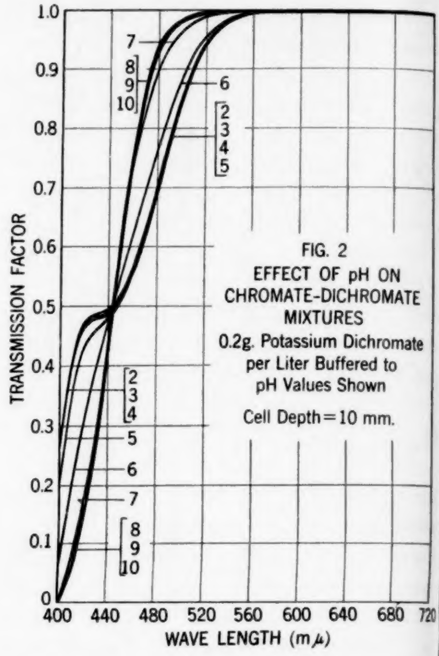
The spectrophotometric curves obtained from the Muer and Hale standards, composed of acid mixtures of copper sulfate and potassium dichromate, are strikingly different from the other curves. It is evident that this composition does not give curves that are close spectrophotometric matches of the temporary chlorine standards. The absorption in the red portion of the spectrum, which produces a second minimum in the curve, is due to the copper sulfate which was added to the potassium dichromate so that visual matches with the temporary chlorine standards could be obtained.

Fortune (4) points out that, when two minima are present, dichromatism is displayed; i.e., a change in hue occurs when the color is viewed through different cell depths and in different lights. This subject is discussed by Clark (5, p. 161). The effect of dichromatism on the Muer and Hale standards is discussed by Dragt (6) and Griffin (7). As the cell depth of a given temporary and of a Muer and

* In the temporary standards, described in Part I of this paper covering ortho-tolidine-chlorine colors (1), the number of color molecules per unit volume represent only 95 per cent of the chlorine molecules per unit volume originally present in the chlorine water. Therefore, the color for only 95 per cent of chlorine molecules originally present in the water is observed. In the existing permanent chlorine standards, the color representing 100 per cent of chlorine molecules is observed.

Hale permanent chlorine standard decreases, the color decreases in intensity, but the colors are no longer matches. The copper sulfate-potassium dichromate color becomes increasingly yellower with decreasing cell depths. This is caused by the fact that the permanent standard increases in transmission at the red end of the spectrum, thus pushing the observed color toward this end of the spectrum, and the fact that the ortho-tolidine-chlorine color did not increase in transmission at the red end of the spectrum, for its transmission was already 100 per cent.





From these observations it would appear that the amount of copper sulfate would have to be altered as the cell depth decreases, to compensate for the effect of dichromatism. Daniels (8), in preparing permanent chlorine standards composed of copper sulfate-potassium dichromate for cell depths of 13, 26 and 52 mm., had to use a different ratio of copper sulfate to potassium dichromate for each cell depth. Similarly, Donahue and Zimbon (9), in using a 32-mm. cell depth, found a different ratio of copper sulfate to potassium dichromate than that used in existing standards for 240- and 300-mm. cell depths.

The spectrophotometric curve of Scott's standard (Fig. 1, Curve 3) composed of chromate-dichromate and boric acid-borate buffer (10, 11) and prepared according to the directions given in the latest edition of *Standard Methods* (3) is strikingly different from the equivalent copper sulfate-potassium dichromate curves and strikingly similar to the equivalent temporary standard curve. Scott's chromate-dichromate spectrophotometric curve (Curve 3), like the temporary chlorine standard's spectrophotometric curve (Curve 4), contains only one minimum and therefore does not display dichro-

matism. For this reason Scott's chromate-dichromates can be used at all cell depths.

Although Scott's chromate-dichromate is similar to the temporary chlorine standards, it definitely is not as close a spectrophotometric match as desirable. In view of the fact that the new temporary chlorine standards are darker in color than any of the previous standards, including Scott's, and are of a slightly different hue, the Scott standards require some modification in order to make satisfactory matches.

Since the temporary chlorine standards obey Beer's law up to 1.5 ppm., it is essential that Scott's chromate-dichromate, when modified, obey Beer's law in this range; and, in this same range, it is necessary for the chromate-dichromate to compensate for the characteristic minimum at 436 mμ, shown in Fig. 4 (p. 1210), which, as pointed out by Dragt and Mellon (12) is peculiar to ortho-tolidine-chlorine colors. Due to the fact that the sensitivity of the eye is very low in this region of the spectrum, this is not a serious difficulty. Since the temporary chlorine standards deviate from Beer's law at a constant rate from 1.5 ppm. to 10 ppm., it is essential that Scott's chromate-dichromate, when modified, also deviate from Beer's law in a similar manner.

Fortunately, chromate-dichromate solutions can be made to obey or disobey Beer's law. An understanding of chromate-dichromate solutions, particularly in relation to Beer's law, is obviously pertinent in obtaining the modified and practical set of Scott chromate-dichromate standards.

Temporary Standards *vs.* Buffered Chromate-Dichromate Solutions

Dichromate ions ($Cr_2O_7^{--}$) produce a color that is yellower in hue than most ortho-tolidine-chlorine colors. Chromate ions (CrO_4^{--}) produce a color that is greener in hue than most ortho-tolidine-chlorine colors. At some mixture of the two, a color is produced that is a match to that of each chlorine residual. Since acid solutions favor the formation of dichromate ions and alkaline solutions favor the formation of the chromate ions, the variations in the color become merely a matter of pH adjustment.

This is illustrated * by the spectrophotometric curves appearing in Fig. 2 which shows the fluctuation in color that results from altering the pH of a solution of 0.2 g. potassium dichromate per liter. At a pH of 2.0–6.0 the color is the yellowest, for the solution is primarily one containing dichromate ions. At a pH of 8.0–10.5 the color is the greenest, for the solution is primarily one containing chromate ions. The shift in color is most pronounced between pH values of 6.0 and 7.0, for this is the pH range over which the greatest shift from dichromate to chromate and vice versa occurs. This can be shown by determining the pH of various mixtures of potassium dichromate and potassium chromate. A solution within the range of Scott's present standards containing potassium dichromate and potassium chromate in the ratio of 80:20 has a pH of approximately 6.0. A solution of similar strength containing potassium dichromate and potassium chromate in the ratio of 20:80 has a pH of approximately 7.0.

* This curve, obtained from Dr. R. E. Kitson, Purdue Univ., is used with his permission. Ref: Unpublished thesis for doctorate, Purdue Univ., Lafayette, Ind. (1943).

From this evidence it is seen that the chromate-dichromate ratio, and therefore the color, can be altered by merely changing the pH of any given chromate-dichromate mixture (as shown in Fig. 2). This opens the way for making the modified Scott chromate-dichromate standards deviate from Beer's law in a manner similar to the temporary standards above 1.5 ppm.

It is generally conceded that properly buffered chromate-dichromate solutions do obey Beer's law. In the modified Scott chromate-dichromate standards up to 1.5 ppm., the color can be made to do this by fixing the chromate-dichromate ratio. In order to fix the ratio, the pH must be maintained constant. Chromate-dichromate solutions are in themselves buffers, but since their concentration is different in each standard, variation in pH would occur if no additional buffer were present. Furthermore, the concentration of the chromate-dichromate is so small in the lower standards that the buffering effect would be poor in this case. Thus, especially in the lower standards, the addition of an efficient buffer is necessary. These characteristics of buffered and unbuffered mixtures show why the literature contains evidence indicating that chromate and dichromate solutions in some instances obey Beer's law and in some instances do not obey Beer's law.

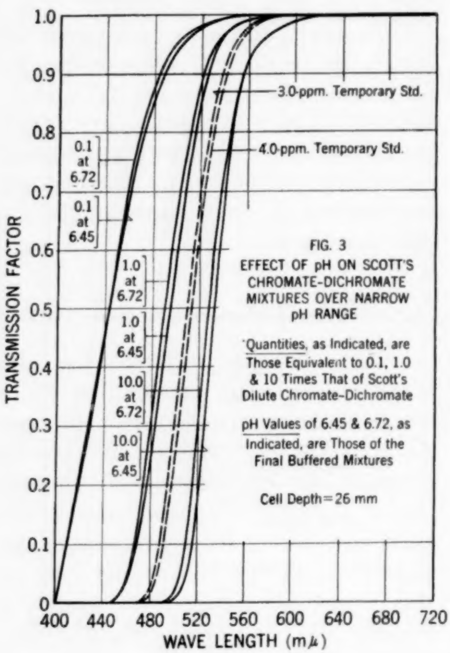


FIG. 3
EFFECT OF pH ON SCOTT'S CHROMATE-DICHROMATE MIXTURES OVER NARROW pH RANGE

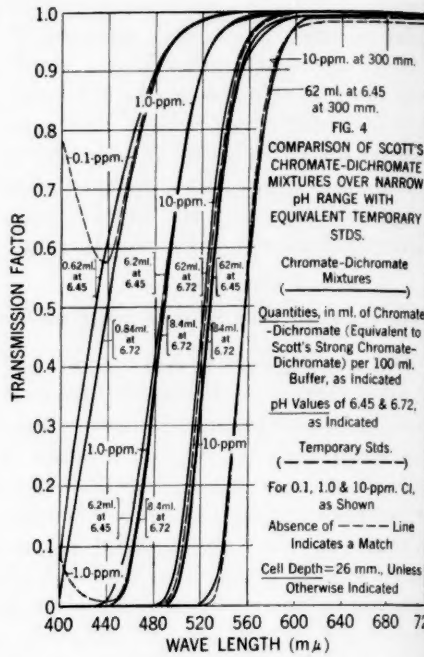


FIG. 4
COMPARISON OF SCOTT'S CHROMATE-DICHROMATE MIXTURES OVER NARROW pH RANGE WITH EQUIVALENT TEMPORARY STDS.

Since the unbuffered chromate-dichromate used by Scott had an approximate pH of 6.7 and his buffer solution had an approximate pH of 6.5, a study of chromate-dichromate mixtures covering this range was made. To do this, solutions were made up and buffered so as to keep the pH and ratio of chromate to dichromate constant, thereby making them obey Beer's law. Spectrophotometric curves for solutions of 0.1, 1.0 and 10 times the

strength of Scott's dilute chromate-dichromate, buffered at pH values of 6.72 and 6.45, are shown in Fig. 3. The curves for the 0.10 strength solution cross each other as do those for similar low concentrations of chromate-dichromate given in Fig. 2. The other curves, representing high concentrations, do not cross each other, but those for pH 6.45 are to the right of those for pH 6.72, indicating that the color is more intense at pH 6.45. That this difference is considerable is seen by comparing these curves with those representing the 3.0- and 4.0-ppm. temporary chlorine standards at the same cell depth. Furthermore, it was found that 62 ml. of Scott's strong chromate-dichromate diluted to 100 ml. at pH of 6.45 and 84 ml. of the same diluted to 100 ml. at pH 6.72 are close spectrophotometric matches, as shown in Fig. 4. These comparisons indicate that the pH of the chromate-dichromate standards must be maintained within very narrow limits in order to obtain reproducible colors. As explained later, this can be done.

It is evident from the above discussion that definite pH values must be decided upon, since only one pH can be used if the standards are to obey Beer's law. Spectrophotometric curves of chromate-dichromate solutions at pH values of 6.45 and 6.72, in quantities proportional to the chlorine residuals, are given in Fig. 4 together with those of equivalent temporary standards.

A study of these curves at pH 6.72 shows that, although they are a close match at 1.0 ppm., they are not a match at 0.1 ppm. Thus a set of standards employing a pH of 6.72 would not have the quantities of chromate-dichromate proportional to the chlorine residual.

A study of these curves at pH 6.45 shows that the curves at the two lower residuals, 0.1 and 1.0 ppm., match at the higher transmission values and cross the minima of the chlorine curves at the lower transmission values. Dragt (6) has shown that curves which are thus spectrally balanced are visual matches at all cell depths. Thus, it would appear possible to construct a set of standards having a pH of approximately 6.45 which would have the quantities of chromate-dichromate proportional to the chlorine residuals up to 1.0 ppm. and would be usable at all cell depths.

A study of the curves at pH 6.45 and 10 ppm. chlorine shows that the colors for the chromate-dichromate curves are darker than the temporary standards at both 26- and 300-mm. cell depths, particularly darker at the former. Since the temporary standards are lighter at 10 ppm. than they would be if they obeyed Beer's law, this result is to be expected. Thus, as noted before, it will be necessary to make the chromate-dichromate disobey Beer's law in this range. The only way to accomplish this without making the quantities for all residuals disproportional is to change the pH.

Since the permanent standard must be lighter, the pH must be raised. If the pH is raised to 6.72 and the proportional quantity (62 ml.) used, the color is too light at the 26-mm. cell depth. It is obvious that the pH need not be raised this high in order to obtain a match with the proportional quantity at a 26-mm. cell depth. However, at 300-mm. cell depth, where the proportional quantity at pH 6.45 crosses the chlorine curve, even less elevation of the pH would be required to obtain a match.

From this it is evident that a set of standards having quantities of chromate-dichromate proportional to the

residual and usable at all cell depths, cannot be obtained in the range of 1.5 to 10.0 ppm. chlorine even when pH is increased. This is to be expected since the temporary standards in this range do not have identical spectral characteristics. A satisfactory method has been devised for automatic elevation of pH with increasing residuals, so that quantities of chromate-dichromate proportional to the residual can be used at any one cell depth.

This is accomplished in a practical manner by utilizing the buffering effect of the chromate-dichromate mixture. If the unbuffered chromate-dichromate mixture has a higher pH than the phosphate buffer used, the pH of the standards will increase as the residual increases, since the chromate-dichromate content increases in relation to the amount of buffer at the higher residuals. The pH of the chromate-dichromate, however, must not be so high that the desired constant pH is upset for chlorine standards up to 1.5 ppm. This will permit only a slight elevation in pH for the 10-ppm. chlorine residual and since the least elevation in pH is necessary at the 300-mm. cell depth this is the only cell depth at which quantities of chromate-dichromate directly proportional to the chlorine residual can be secured in this manner. If this is done, the 10-ppm. standard for 300-mm. cell depth can be used as the stock solution for all other residuals at all other cell depths. If the pH could have been raised sufficiently to make the standards at 26-mm. proportional to the chromate-dichromate, the 10 ppm. standard at 300-mm. would then require extra chromate-dichromate, thereby eliminating its use as a stock solution for all other residuals in quantities proportional to these residuals.

Since the pH for the match with the 10-ppm. temporary standard at 300-mm. cell depth has to be raised only slightly, visual matches at this cell depth were made with the proportional quantity of chromate-dichromate (62 ml. per 100 ml. buffered with pH 6.45, 0.1 *M* phosphate buffer). Various ratios of chromate-dichromate having unbuffered pH values between 6.45 and 6.72 were used. The chromate-dichromate having a ratio of 75 : 25 of each by weight and an unbuffered pH of approximately 6.72 gave the desired balance. This was the ratio used by Scott.

Visual Matching of Temporary Standards

Most of the work described above was accomplished spectrophotometrically. Since perfect spectrophotometric matches were unobtainable, however, slight adjustments were required as the result of visual matching.

Principle of Color Matching

To make an intelligent interpretation of the results of visual matching, it is necessary to know what tolerance or "closeness" of the readings can be expected. The discernible differences, as parts per million of chlorine, are not the same for all chlorine residuals. For instance, although a difference of 0.01 ppm. chlorine is easily discernible at a 300-mm. cell depth for the 0.10-ppm. chlorine standard, this difference is definitely not noticeable for the 1.0-ppm. or 10-ppm. chlorine standard at the same cell depth.

These facts are explained by the Weber-Fechner law, relating to the

stimulation of the senses. The law states that the sensation is proportional to the logarithm of the stimulus, meaning that the least noticeable difference in residual is always a constant percentage of the residual being observed. Thus, equal percentage differences between prorated quantities of chromate-dichromate should be discernible at all residuals. The prorated quantity may be expressed as the number of milliliters of chromate-dichromate per 100 ml. of standard per given unit of chlorine residual. The ability of various individuals to perceive differences is remarkably the same. For all individuals, however, the law applies only over a certain range. The lower limit of the range in this case is for chlorine residuals of approximately 0.10 ppm. at 26-mm. cell depth and the upper limit is for chlorine residuals of approximately 10 ppm. at 300-mm. cell depth. That is why it is impractical to determine colorimetrically chlorine residuals above 10 ppm. with ortho-tolidine unless some type of dilution or a very small depth is used.

In visually matching each temporary chlorine standard, several sets of chromate-dichromate standards, each based on a different prorated quantity of chromate-dichromate, were used. The differences between each successive standard averaged 3.33 per cent of the total chlorine residual. In the range of color where perception was good, it was possible to estimate a match visually halfway between two successive chromate-dichromate standards. The difference in this case averaged 1.67 per cent of the total chlorine residual. Any estimation of a match closer than this was found to be a mere guess, since such an estimation was not reproducible.

Final Selection of pH of Buffer

To make certain that the pH of the buffer to be used for the permanent chlorine was correct, some of the new temporary chlorine standards were matched visually with chromate-dichromate standards. These standards were prepared by using Scott's stock quantities of chromate-dichromate dissolved in and diluted within 0.1 M phosphate buffer having pH values of 6.40, 6.45 and 6.50. All measurements were made under the light conditions described on page 1216. The results appear in Table 3 as prorated quantities of chromate-dichromate.

TABLE 3

Prorated Quantities of Scott's Chromate-Dichromate Required for Visual Matching of the New Temporary Chlorine Standards Using Buffers of Various pH Values

Temporary Std.	Cell Depth	Prorated Quants. Using Buffers of pH:		
		6.40	6.45	6.50
ppm. Cl	*mm.*	*ml.*	*ml.*	*ml.*
0.1	26	0.60	0,61	0.62
	300	0.57	0.625	0.64
1.0	26	0.56	0.62	0.62
	300	0.56	0.62	0.62
10.0	26	0.44	0.49	0.50
	300	0.58	0.63	0.64

It will be noted that the chromate-dichromate prorated quantities for 10 ppm. chlorine at 26-mm. cell depth vary so widely from the average that they must be discarded in any consideration of the proper pH. An inspection of the other prorated quantities, however,

indicates definite trends. It appears that the least deviation from an average occurs when using a buffer of pH 6.45.

Final Matching of Permanent Standards up to 1.0 ppm.

On the basis of these results, visual measurements were made with standards prepared by using Scott's quantities of dilute chromate-dichromate dissolved in and diluted with 0.1 *M* phosphate buffer of pH 6.45.

Measurements were first made at 26-mm. and 300-mm. cell depths with the 0.05-, 0.10-, 0.20-, 0.30-, 0.40-, 0.50-, 0.60-, 0.80- and 1.0-ppm. temporary chlorine standards. All measurements gave prorated quantities close to 0.62 ml., some being slightly higher and some slightly lower. In terms of parts per million chlorine, the use of the 0.62-ml. prorated quantity for all the chlorine residuals would produce a maximum error of 0.005 ppm. chlorine at the 26-mm. cell depth and a maximum error of 0.01 ppm. chlorine at the 300-mm. cell depth. The error is positive at low residuals and negative at higher residuals for the 26-mm. cell depth. At the 300-mm. cell depth, the reverse is true. As the colors are not perfect spectrophotometric matches, this was expected. Since the deviations are within the experimental error and are both positive and negative this is evidently the desired set of standards for residuals up to 1.0 ppm.

It will be noted that the figures given in the data above are on the basis of the quantities used in Scott's stock dilute chromate-dichromate (0.75 g. potassium chromate (K_2CrO_4) and 0.25 g. potassium dichromate ($K_2Cr_2O_7$) per liter). In setting up Table 1, however, the strength was altered (0.465 g. K_2CrO_4 and 0.155 g. $K_2Cr_2O_7$ per liter) so that the prorated quantity would be 1.00 ml., and this stock dilute chromate-dichromate would be the 1.0-ppm. standard for all cell depths.

Final Matching of Permanent Standards, 1.0 to 10 ppm.

Visual measurements were then made with standards prepared by using Scott's quantities of strong chromate-dichromate dissolved in and diluted with 0.1 *M* phosphate buffer of pH 6.45. Matches were made at 26-, 50-, 100-, 200- and 290-mm. cell depths with the 1.5-, 2.0-, 3.0-, 4.0-, 5.0-, 6.0-, 8.0- and 10.0-ppm. temporary chlorine standards. All measurements gave prorated quantities close to 0.62 ml. at the 290-mm. cell depth. For the 200-mm. cell depth, the prorated quantity decreased from 0.62 ml. at 1.5 ppm. chlorine to 0.60 ml. at 3.0 ppm. chlorine and remained at that figure for all residuals up to 10 ppm. chlorine. A graphical study of the prorated quantities indicated that a 0.62-ml. prorated quantity would apply to all cell depths from 240 mm. to 300 mm. Since the prorated quantities went from 0.60 ml. at the 200-mm. cell depth to 0.62 at the 290-mm. cell depth, the use of the 0.62-ml. prorated quantity for all chlorine residuals at cell depths at 240 to 300 mm. would produce a maximum error of only 0.16 ppm. Since this maximum error occurs with the 10-ppm. standard, it is hardly detectable. For the 100-mm. cell depth the prorated quantity decreased from 0.62 ml. at 1.5 ppm. chlorine to 0.52 ml. at 8.0 ppm. chlorine and stayed at 0.52 ml. for 10 ppm. chlorine. For the 26-mm. and 50-mm. cell depths, the prorated quantities were almost identical for each chlorine residual, and varied from 0.62 ml. at 1.5 ppm. chlorine to 0.495 ml. at 10 ppm. chlorine.

It will be noted that the figures given in the data above are on the basis of the quantities used in Scott's stock strong chromate-dichromate (7.5 g. potassium chromate (K_2CrO_4) and 2.5 g. potassium dichromate ($K_2Cr_2O_7$) per liter). In setting up Table 2, however, the strength was altered (4.65 g. K_2CrO_4 and 1.55 g. $K_2Cr_2O_7$ per liter) so that the prorated quantity would be 1.00 ml. and this stock strong chromate-dichromate the 10-ppm. standard for the 240–300-mm. cell depths.

Buffer Solutions Used in the Standards

As previously pointed out the color of the standards is greatly dependent upon their pH values. This requires the use of an efficient buffer. The only efficient buffers at pH 6.45 are the phosphates and those prepared from organic acids. Since organic acids are not readily obtainable in pure form and since they are likely to decompose, yielding colored products, their use is not advisable.

Unfortunately, the boric acid-borate buffer, which is an excellent buffer at more alkaline pH values, is not efficient at pH 6.45.

Using Van Slyke's formula (5, p. 56) for calculating β or "buffering power," the following values are obtained for a 0.1 *M* buffer at pH 6.45. β for the phosphate buffer is 0.053 and β for the borate buffer is 0.00041. These figures indicate that the phosphate buffer is more than 100 times as effective as the boric acid-borate at this pH. Obviously, the concentration of the borate buffer could not be increased sufficiently to approach the efficiency of the phosphate buffer. Thus, the use of phosphate buffer is a necessity, as it is the only one suitable for the purpose.

The disadvantage in using a phosphate buffer is that, when prepared from commercially available salts, it yields a turbid solution which later develops into a characteristic floc similar to an organic growth.

This impurity is believed by Clark (5, p. 194) to be an aluminum compound. He suggests a method of preparing salts free from this contaminant. The authors have used this method with good results. It is, however, too laborious to be used as a general procedure. An easier and equally satisfactory method is simply to allow the aluminum floc to form completely and then to remove it by filtration. This is best done using a 0.5 *M* stock solution. Naturally, the longer the solution is allowed to stand before filtering, the more satisfactory the filtered solution is likely to be. Solutions filtered after one week's storage were still clear six months after filtering. Solutions filtered a few days after preparation may later develop a slight turbidity.

The phosphate buffer is prepared from a primary and a secondary phosphate. For the primary salt, primary potassium phosphate (KH_2PO_4) is used, since this salt is purer than the corresponding sodium salt and, not being hydroscopic, requires no drying. For the secondary salt, either anhydrous secondary sodium phosphate (Na_2HPO_4) or secondary sodium phosphate dihydrate ($Na_2HPO_4 \cdot 2H_2O$) is used, since these salts are purer than the corresponding potassium salts. Secondary sodium phosphate dodecahydrate ($Na_2HPO_4 \cdot 12H_2O$) is not recommended for preparing an accurate set of standards, since it is likely to contain an indefinite amount of water. In an emergency, however, clear crystals of this salt could be used.

The Na_2HPO_4 must be anhydrous and, since it is likely to contain some water, must be dried at 110°C. and cooled in a desiccator before weighing. The $Na_2HPO_4 \cdot 2H_2O$ may be obtained by exposing the $Na_2HPO_4 \cdot 12H_2O$ to an atmosphere having a humidity between 29 and 59 per cent until the weight is constant. This requires approximately two weeks. The most reliable method of doing this is to place the salt in a desiccator containing a saturated potassium carbonate (K_2CO_3) solution, considerable undissolved potassium carbonate being present at all times. Once obtained the $Na_2HPO_4 \cdot 2H_2O$ may be kept in a bottle ready for use.

The authors have prepared buffers using Na_2HPO_4 and $Na_2HPO_4 \cdot 2H_2O$ prepared as outlined above by starting with both commercial and specially prepared chemically pure salts. Using apparatus and a technique that gave a precision of 0.005 pH unit, pH determinations were made on these buffer solutions. In all cases, the pH values of the various solutions were the same within the experimental error. The pH values of the solutions were not changed by filtering out the turbidity.

The 0.5 M *phosphate buffer* contains 0.339 mols, 46.14 g., primary potassium phosphate (KH_2PO_4) per liter and either 0.161 mols, 22.86 g., anhydrous secondary sodium phosphate (Na_2HPO_4) or 0.161 mols, 28.66 g., secondary sodium phosphate dihydrate ($Na_2HPO_4 \cdot 2H_2O$) per liter. Since both Na_2HPO_4 and $Na_2HPO_4 \cdot 2H_2O$ give equally good results, the choice is a matter of convenience.

The 0.1 M *phosphate buffer* is obtained by filtering and diluting 200 ml. of the 0.5 *M* phosphate buffer to 1.0 liter with distilled water.

The required quantities of phosphate salts given above were calculated from Cohn's table (5, p. 217). In the previous discussion the authors have, for convenience, specified a pH of 6.45 without stating how such an exact pH is obtainable. They firmly believe that more accurate results can be produced in this type of work by extra care in making up the buffer solutions rather than by adjusting them in accordance with any error that seems to be apparent as show by a pH meter. Since pH determinations, as ordinarily made, can be in error by as much as 0.1 pH unit, 0.1 *M* phosphate buffer should not be checked in this manner. The 0.1 *M* phosphate buffer, however, may be used, if desired, to check a pH meter.

The data presented in this paper indicate that an error of 0.01 pH unit will produce an error of about 1 per cent in the permanent standards. Calculations indicate that a 1 per cent error in weighing either of the salts would be necessary to produce this change in pH. Thus, it can be seen that the pH is easily maintained at the proper value if the standards are prepared by weighing out the exact quantities of the salts specified. Furthermore, since the buffering effect of the phosphates is modified by the buffering effect of the chromate-dichromate used, it is evident that no other buffer salts, except those given herewith, can be used.

Illuminants Used for Matching

In making the visual determinations trouble was experienced, particularly on cloudy days, in making color matches. As a result an artificial illuminant, approximating daylight, was used.

This artificial daylight was based upon the recommendations of the Subcommittee on Color of the American Society for Testing Materials (13). For the purpose of measuring petroleum samples colorimetrically, this com-

mittee determined the characteristics of certain filters, capable of passing light similar to that of a clear blue sky. Upon this basis, the use of filters having a thickness equivalent to 182–202 mireds, i.e., microreciprocal degrees (mr°), with a 60-watt "Mazda" lamp, was recommended.

For the visual determinations made in this work, more light than obtainable from a 60-watt lamp was desired. Actually a 150-watt "Mazda C" lamp, clear envelope, which operates at a slightly higher initial color temperature than the 60-watt lamp, was used. The use of this lamp was compensated for by altering the mired specification of the filter. The 150-watt lamp used in conjunction with a "Corning No. 5900" filter of thickness equivalent to 160–180 mireds and a white diffuser glass was satisfactory and approximated average north daylight. The white diffuser glass, placed between the filter and the standard, was of sufficiently low transmission to exclude any outline of the lamp filament and sufficiently white so as not to show selective absorption in any part of the spectrum.

Matching was also tried using indirect light from "daylight" fluorescent lamps such as those manufactured by the General Electric Co. and the Westinghouse Co. Their use was found satisfactory for reading chlorine residuals with the permanent chlorine standards.

The authors recommend the use of the artificial illuminants mentioned above for this type of work. The many readings taken with these illuminants, as well as in daylight, indicate that the results with the artificial illuminants are comparable with average good daylight but are vastly superior to poor and varying daylight.

Precaution in Use of Standards

In Part I of this paper (1), attention was called to the fact that the viewing depths of the standards and samples must be identical and that the chlorine molecules, or color molecules equivalent to them, must be the same per unit volume at all times.

In the new temporary chlorine standards, 100 ml. of chlorine water are added to 5 ml. of ortho-tolidine reagent, so that the number of color molecules per unit volume represents only 95.2 per cent of the chlorine molecules per unit volume originally present in the water. If desirable, 95 ml. of chlorine water can be added to 5 ml. of ortho-tolidine reagent making the number of color molecules 95.0 per cent in this case. If either standards are used the difference in number of color molecules is only 0.2 per cent, a difference not noticeable to the eye. The proportion of chlorine water to ortho-tolidine reagent mentioned above should be used at all times, so as to maintain a strength of 95 per cent. Thus, a 15-ml. cell requires 0.75 ml. ortho-tolidine reagent.

Under no circumstances is the 105 ml. portion of ortho-tolidine-chlorine color to be poured into the Nessler tube above the 100 ml. mark at the 240-mm. or 300-mm. cell depth. If this were done the comparison would be made with 100 per cent of the color molecules and, since cell depths would be different, the reading would be in error by 5 per cent. Since standards for all cell depths are being discussed, all comparisons between the new permanent standards and the temporary chlorine standards were made at identical cell depths. It should be noted that this procedure is not the same as that in present use. However, it is the only procedure that can be used with standards designed for all cell depths.

Spectrophotometric Comparisons of Permanent Chlorine Standards

A spectrophotometric comparison of the permanent and temporary standards was made in order to check the accuracy of the visual matching. The spectrophotometric curves of both standards, for chlorine values of 0.10, 1.0 and 10.0 ppm., at 26-mm. and 300-mm. cell depths appear in Figs. 5 and 6, respectively. It is to be noted that in no instance are the dotted curves of the temporary standards completely coincident with the solid curves of the permanent standards, for, as previously pointed out, exact spectrophotometric matches could not be obtained. But since they are close spectrophotometric matches and the deviations appear to be spectrally balanced by the crossing of the curves as noted above, the curves indicate that the standards are close visual matches.

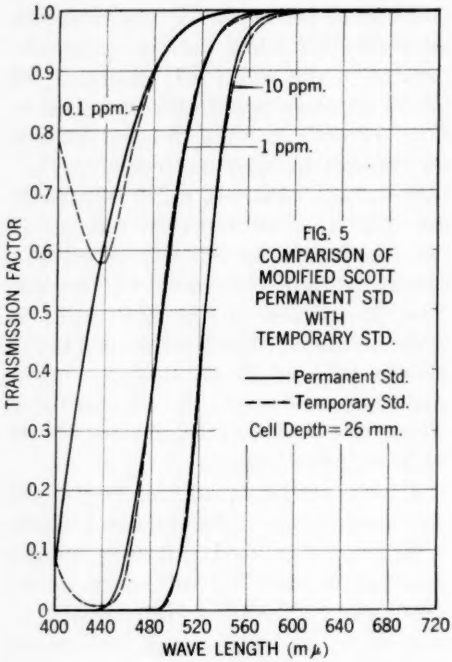


FIG. 5
COMPARISON OF MODIFIED SCOTT PERMANENT STD WITH TEMPORARY STD.

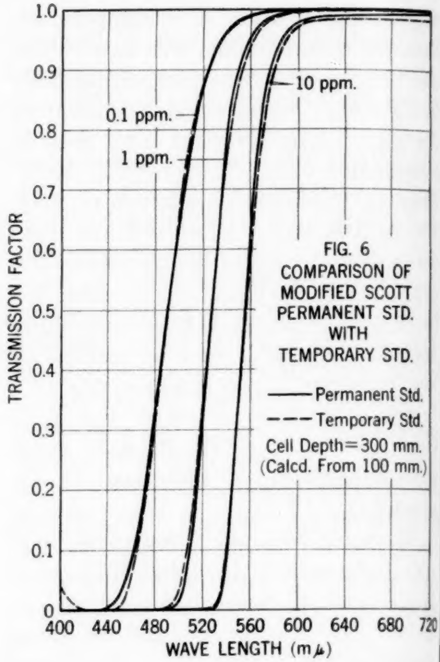


FIG. 6
COMPARISON OF MODIFIED SCOTT PERMANENT STD. WITH TEMPORARY STD.

Since the spectrophotometric curves are not exact spectrophotometric matches, certain monochromatic data from the transmission curves of both standards are presented to verify that the standards are good visual matches.

The "weighted ordinate" method is used. As pointed out by Hardy (14) this procedure is very tedious and open to computational errors. The tristimulus values of illuminant *C* (daylight) for each of the three primaries, red, green and blue, respectively designated as *X*, *Y* and *Z*, are calculated by summing the products obtained by multiplying the transmission factors of certain selected wave lengths by their respective tristimulus values. The values of *X*, *Y* and *Z* for a given standard and cell depth also depend upon the number of wave lengths selected. The

wave lengths were taken at average * intervals of 5 mμ over the range from 400 mμ to 700 mμ. Since it was impossible to make determinations at all cell depths, the transmission factors for other cell depths are calculated from those determined at 26 mm. and 100 mm. These values are given in Table 4, from which all other monochromatic data may be obtained. The relative

* Since the cross-section paper employed was marked at 2 mμ intervals, the following wave lengths were chosen: 400, 406, 410, 416 . . . 700 mμ.

TABLE 4

Comparison of the Tristimulus Values of Various Temporary and Permanent Chlorine Standards

Chlorine, *ppm.*	*X* (For Red Primary)		*Y* (For Green Primary)		*Z* (For Blue Primary)	
	A*	B†	A*	B†	A*	B†
			At 26-mm. Cell Depth			
0	2084.8	2084.8	2128.7	2128.7	2509.5	2509.5
0.10	1952.1	1948.3	2099.0	2099.4	1804.8	1797.7
0.20	1868.4	1869.4	2075.7	2078.8	1356.8	1371.3
0.50	1748.8	1756.9	2025.8	2028.7	692.3	744.8
0.75	1711.8	1714.8	1995.6	1989.4	477.2	494.4
1.00	1689.2	1693.4	1964.1	1962.1	340.7	360.0
1.50	1672.5	1674.8	1925.2	1921.6	231.2	234.4
			At 300-mm. Cell Depth			
0	2084.8	2084.8	2128.7	2128.7	2509.5	2509.5
0.10	1677.3	1684.9	1939.2	1943.0	293.0	320.6
0.20	1654.0	1654.3	1858.8	1860.8	134.7	146.3
0.50	1627.9	1628.4	1712.5	1705.0	49.1	44.4
0.75	1610.0	1615.0	1627.1	1630.9	31.3	28.0
1.00	1598.0	1607.4	1573.3	1581.0	23.5	20.8
1.50	1573.4	1587.0	1483.7	1497.1	15.2	13.8
			At 26- and 52-mm. Cell Depth (Average)			
1.50	1661.0	1663.4	1876.5	1873.4	167.3	166.9
3.00	1641.8	1643.8	1780.5	1773.6	83.6	79.3
5.00	1624.3	1630.0	1687.0	1692.8	45.9	44.4
8.00	1602.4	1616.8	1582.3	1619.1	25.3	27.5
10.00	1589.9	1603.7	1536.1	1563.0	20.1	20.6
			At 240- and 300-mm. Cell Depth (Average)			
1.50	1581.0	1593.3	1510.1	1520.5	17.3	15.5
3.00	1533.9	1548.9	1362.3	1375.4	9.1	8.4
5.00	1488.6	1497.6	1243.1	1248.4	5.6	5.1
8.00	1423.1	1445.8	1114.0	1144.9	3.4	3.5
10.00	1394.3	1418.8	1059.7	1091.7	2.8	2.9

* A = Temporary Chlorine Standards.
† B = Modified Scott Permanent Chlorine Standard.

brightness or relative transmission of the standards may be obtained by dividing their Y values by the Y value for 100 per cent transmission, which is 2128.7, as given in the table.

Using the table for a comparison it is found that the deviation of the permanent standards from the temporary standards is both positive and negative up to 1.50 ppm. Since the deviations are not always in the same direction as those obtained from visual matches, it is apparent that the temporary and permanent standards are very close matches. In the range above 1.5 ppm. it would appear, from the spectrophotometric data, that the 8- and 10-ppm. standards are somewhat lighter. Since the ortho-tolidine-chlorine colors display a slight amount of dichromatism at these residuals, the calculations are not strictly applicable.

The trichromatic values of the standards for the three primaries, red, green and blue, respectively designated as x, y and z are given in Table 5. The value x is calculated by dividing X by the sum of X, Y and Z; y and z are similarly calculated. Since x, y and z total 100 per cent only x and y are given.

Using this table for comparison of the chromaticity of the colors, it is seen that the values for the chlorine residuals up to 5.0 ppm. are remarkably close. The hues of the temporary and permanent standards for these residuals are practically identical. Although the chromaticity figures for the 8- and 10-ppm. standards are not as

TABLE 5

*Comparison of the Trichromatic Values (per cent) or Chromaticity of Various Temporary and Permanent Chlorine Standards**

Chlorine, *ppm.*	x (Red), in %		y (Green), in %		x (Red), in %		y (Green), in %	
	A†	B‡	A†	B‡	A†	B‡	A†	B‡
	At 26-mm. Cell Depth				*At 300-mm. Cell Depth*			
0	31.01	31.01	31.66	31.66	31.01	31.01	31.66	31.66
0.10	33.34	33.33	35.84	35.93	42.90	42.67	49.60	49.21
0.20	35.25	35.14	39.16	39.08	45.35	45.17	50.95	50.84
0.50	39.15	38.78	45.35	44.78	48.03	48.21	50.52	50.47
0.75	40.91	40.84	47.69	47.38	49.26	49.33	49.78	49.82
1.00	42.29	42.17	49.18	48.86	50.00	50.09	49.23	49.26
1.50	43.68	43.72	50.28	50.16	51.22	51.22	48.29	48.32
	At 26- and 52-mm. Cell Depth (Avg.)				*At 240- and 300-mm. Cell Depth (Avg.)*			
1.50	44.87	44.96	50.67	50.60	50.87	50.91	48.58	48.59
3.00	48.86	47.05	50.78	50.72	52.80	52.82	46.89	46.90
5.00	48.41	48.43	50.24	50.26	54.39	54.44	45.41	45.38
8.00	49.95	49.57	49.28	49.59	56.02	55.74	43.84	44.13
10.00	50.57	50.40	48.80	49.01	56.76	56.46	43.13	43.43

* z (Blue), in % = 100 − (x in % + y in %).
† A = Temporary Chlorine Standards.
‡ B = Modified Scott Permanent Chlorine Standards.

close as for the lower residuals, they indicate the difference in hue is not noticeable.

Since chromaticity is an important factor in obtaining visual matches, the figures indicate that a very satisfactory set of standards has been obtained.

Summary

An attempt was made to prepare a set of permanent chlorine standards for residuals up to 10 ppm., each standard of the set to be usable at all cell depths and to be prepared by a proportional dilution of a stock solution representing 10 ppm. chlorine.

The recommended standards meet these requirements except that the standards for residuals above 1.5 ppm. at cell depths less than 240 mm. are not prepared by proportional dilution.

The standards are a modification of Scott's chromate-dichromate standards.

All standards are 0.1 *M* with respect to phosphate buffer. The buffering effect of the chromate-dichromate is balanced against that of the phosphate so as to maintain the proper color of each standard.

The final standards were obtained by visual matching and were checked by spectrophotometric methods.

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Abstracts of Water Works Literature

Key: In the reference to the publication in which the abstracted article appears, **34:** 412 (Mar. '42) indicates volume 34, page 412, issue dated March 1942. If the publication is paged by the issue, **34:** 3: 56 (Mar. '42) indicates volume 34, number 3, page 56, issue dated March 1942. Initials following an abstract indicate reproduction, by permission, from periodicals, as follows: *B.H.—Bulletin of Hygiene (British); C.A.—Chemical Abstracts; P.H.E.A.—Public Health Engineering Abstracts; W.P.R.—Water Pollution Research (British); I.M.—Institute of Metals (British).*

WARTIME WATER WORKS PROBLEMS

New Horizons for Water Service. Edward J. Cleary. Eng. News-Rec. **130:** 827 (June 3, '43). *Where We Stand Today.* Widespread misconception that there will be revolutionary changes in postwar world; hence resistance to undertake tangible, practical planning. Authoritative evidence—from water works mfrs. themselves—shows this viewpoint unsound. Relatively little in way of newly developed materials and equip. should be expected when war terminates and, in fact, may be 1 or 2 yr. before mfrs. in position to produce new equip. In any event, equip. in water treatment plant represents only about 10% of entire cost of installation and, also, if plans and specifications made now, necessary revisions can be made quickly when contracts awarded. First essential to det. how local funds can be made available for postwar work. Important that mfrs. be informed of potential vol. and type of work to be undertaken; should be remembered that materials allocation based on priorities may remain even after peace comes. General agreement that present nation-wide supply facilities not only inadequate in regard to vol. production, but also as regards maintg. higher std. of qual. demanded by public. Elimn. of phys. deficiencies variously estd. to require annual expenditure of 160–200 million dollars for decade following war. In admin. field, evident that integration of munic., county and other relationships in water service cannot be postponed indefinitely—problem characterized by Wolman as provision of utility services to people living within multiple political boundaries. Annexation and formation of metropolitan dists. or public authorities have not provided complete soln. of problem. Water service must be viewed from standpoint of need not revenue. Also problem of political mismanagement, as reflected in no. of employees on payrolls. In survey of 17 cities by Burns and McDonnell Eng. Co., no. of employees found to vary from 58 to 192 per 100,000 pop. Variation of over 3 to 1 does not appear justified. Another issue on which definite stand must be taken is unionism. As general rule, most satisfactory econ. operation of municipally owned water property can be obtained through management by utility board of 3 to 5 members. Tenure usually longer than that of other classes of city officials, ensuring greater consistency and continuity of policy and greater freedom from political interference. Among fiscal problems are diversion of water works revenue to general funds of municipality and need for revision of rate schedules. Avg. charge per 100 cu.ft. of metered water in 11 larger cities varies from 5.1 to 25.8¢. *Facing Tomorrow's Horizons.* Pattern of postwar activity in field of water service might unfold in 4 phases: (1) appraisal, (2) transition, (3) execution, (4) stabilization—first 3 covering period of 12–15 yr. Accomplishments during (1), i.e., from now until end of war, should be detn. of immediate and long-range needs and formulation of suggested reforms in admin., fiscal and legal policies. Point (2) covers interval of 6–12 mo. of adjustment to new conditions, during which there will be immediate need for making repairs and catching up on deferred maint., but vol. of accomplishment in dollars may not be great. During (3), into

which (2) will merge, there should be accelerated rate of new constr. and important changes in practice and equip. may be expected to evolve. After decade of expansion may be presumed that there will be no further acceleration in constr. rate and during stabilization period, major activity will be diverted toward improvement and replacement of obsolescent plant and equip. From '25 to '42, new water works constr. avgd. 84 million dollars annually and in depression decade, '31–'40, when federal aid available, 89 million dollars. Highest was 163 million dollars in '39 and lowest 35 million in '32. One est. of future constr. is about 220 million dollars annually for next decade. Perhaps most compelling problem is wider acceptance of principle and eventual adoption of regional concept for water service. Obvious reasons for ignoring of advantages of joint action and co-operation are fact that both public and private enterprises involved, interstate complications and unwillingness of cities to share supply facilities because of competition for industries. *Evaluating Community Needs.* Improvements fall into 2 classifications: (1) deferred maint., to be undertaken first and (2) major improvements and admin. reforms. In latter, present service should first be evald. and then needs to accomplish desirable goals detd. For those concerned with water qual., article of Shaw & Chase "What is Good Water Worth?" (Eng. News-Rec. **119:** 641 (Oct. 14, '37)) in which authors give dollar value of typhoid prevention and removal of undesirable constituents, instructive. Ests. of pop. growth and decline, industrial expansion or retrenchment, etc., important. Students of urban trends long insisted that many cities must come to realization that their boom days are over and that they should plan for maturity rather than expansion. Prognostications of P. M. Hauser, Asst. Director of Census Bureau, summarized, are of utility in evaln. of war-induced changes in future city growth. In regard to labor unionization in public service, G. R. Clapp declares this is no longer interesting theory but accomplished fact. As far back as '39, some 15% of public employees members of unions. Latest published information on licensing of operators reveals that licenses issued in 8 states and certificates in 13. Action voluntary in 15 states, by authority of law in 4, and by authority of state board regulation in 2. *Trend of Technical Advances.* Canvass of firms representing cross-section of water works mfrs. (excerpts of replies given) shows that war production receiving first attention and that planning for postwar activity negligible thus far. No radical changes expected in design of present products, but minor improvements will be reflected in cheaper equip. that is easier to operate and simpler to maint. Research should be resumed as soon as possible. Types suggested.—*R. E. Thompson.*

Memorandum of Evidence to Be Submitted to Lord Justice Scott's Committee on Postwar Planning in Rural Areas. *Supplemental Report of Exec. Com. of British Water Works Assn., Appendix B.* Off. Circ. Br. W.W. Assn. **24:** 152 ('42). Although further increase in pop. of British Isles not expected, water demand per head will increase owing to increased installation of baths, etc., in dwelling houses. If industries established in rural areas, considerable quants. of water may be required, and it is desirable to safeguard potential supplies. Suitable sites for storage and surface reservoirs should be reserved as no. available limited. In cases where water supplies obtained from upland gathering grounds, recommended that water undertaking be given powers to restrict use of land on gathering ground. Steps which have been taken since '13 to improve water supplies in rural areas outlined; recommended that com. be appointed to review position. Most water resources adjacent to urban areas now utilized, and in future addnl. supplies will have to be obtained from rural areas; therefore important that sources of supply in rural areas should be properly conserved. Supply of water in rural areas generally limited by financial considerations and not by eng. difficulties. Rural councils should have powers to compel owners of premises to make use of piped water supplies and sewerage systems when these available within reasonable distance. Purity of streams and rivers seriously affected by discharge of untreated or inefficiently treated trade effluents. Passing of Public Health (Drainage of Trade Premises) Act, 37, should improve conditions. Appointment of river authorities to enforce various acts recommended. Generally possible to treat water supplies to make them suitable for use by industries.—*W.P.R.*

Wartime Safety Operation of Public Utilities. John Stilwell. Pub. Util. Fort. **31:** 152 (Feb. 4, '43). Public in general holds high regard for safety in work of pub. utils. For many years, accident experience of all industry on decline. From '26 to '41 it

dropped 67%. Pub. utils. experience dropped 76% although in many cases work presents greater hazards. Conversion from peace to wartime production speed occasioned upward trend in accident experience. Presidential proclamation deploring "wastage of human and material resources" urged National Safety Council to stop menace depriving America of 500,000,000 man-days of labor per yr. at tremendous cost. National Safety Council's budget increased through formation of War Production Fund to Conserve Manpower. William A. Irvin, Chairman of Fund, states that 46,300 on-and-off-job deaths among workers and 4,400,000 injuries since Pearl Harbor cannot continue unchecked without becoming serious obstacle to achieving max. war production eff. Council now operating in high gear; planning motor car pooling, staggered working hours and traffic routing; accident prevention systems for shipyards and training Provost Marshal's safety personnel. Traffic control in dimouts and blackouts given attention of Council traffic engrs. Enlisting aid of all public and private agencies in task of driving home to the Am. consciousness necessity of saving manpower for warpower perhaps Council's most important task. Util. industry has suffered slight increase in accident frequency rate which rose to 7% between '40 and '41 but industry as whole rose to 8% in same period. Biggest problem prevention of fatalities in elec. operations. One in 33 reportable injuries death during last 5 yr. in comparison with 1 in 98 for Am. industry as whole. Failure to use prescribed safeguards causes half these tragedies. Pub. utils. should be pacemakers in reversing present accident trend.—*H. J. Chapton.*

Water Supplies and Louisiana's War Effort. J. C. Maher. La. Munic. Rev. **6:** 1: 8 (Jan.–Feb. '43). Owing to military and indus. expansion in state since '40, total ground-water consumption increased approx. 10%, or 50 mgd. Military water requirements range from 100 to 150 gal./man; 1 gal. aviation gasoline, 25 gal.; and 1 lb. of powder, 100 gal. Ground Water Divs. of state and federal geol. surveys investigated and reported on water overdraft problems at Rapides, Grant, LaSalle, Caddo, Bossier, Jefferson Davis and Acacia Parishes. Special studies made at Alexandria, Bunkie, Colfax, Natchitoches, Baton Rouge, New Orleans, Camps Livingston, Beauregard, Claiborne and Ester Field. Prelim. investigations started at Camp Polk, Lake Charles and St. Tammany, Tangipahoa Parishes. In gen., ground-water investigations systematic areal surveys or special investigations. In former, common units parishes, although such physiographic units as valleys and drainage basins used. Survey reports usually confined to gen. occurrence and character of ground water with little discussion of quant. problems. Special investigations generally more intensive and detailed, involving practical application of hydr. principles to water supplies of pop. centers and indus. or extensive irrigation areas where large-quant. ground-water withdrawal from wells causes serious problems of overdraft and safe yield. Such quant. studies involve, for each formation and area: (1) water quant. in storage; (2) proportion of stored water recoverable through wells; (3) avg. natural intake or recharge rate; (4) proportion of recharge recoverable through wells; (5) effect of withdrawals through wells upon water supplies from springs; (6) deg. to which recharge rate increasable; and (7) effect of artificial methods for recharge on surface supplies. Reliable results in most quant. ground-water studies require time. Systematic observations of water levels and records of pumpage should be kept at every water works to provide reliable information for future. Studies require combined efforts of geologists, engrs., operators, chemists, local officials, well drillers and owners. Proper ground-water investigations already alleviated water shortage at Alexandria and large military establishments, saving several hundred thousand dollars in critical materials and developed supplementary water supply at another military site.—*Ralph E. Noble.*

The Work of Geologists on Water Supplies for War Purposes. O. E. Meinzer. Econ. Geol. **38:** 323 (June–July '43). Extensive and effective service by geologists trained in hydrology rendered largely by those of U.S. Geol. Survey; much also by those of state surveys, Army engrs., universities, etc. Leadership in civilian work taken by David G. Thompson with 25-yr. experience in ground-water investigation. From beginning, geologists recognized necessity of contacting Army, Navy, OPM, WPB and other fed. agencies and of rendering prompt and practical service. In '42 fiscal yr. U.S. Geol. Survey reported on ground water at approx. 900 places for Army and Navy establishments and war indus., practically all involving geol. In South-

western Div. of Army Engrs., U.S. Geol. Survey advises on water supply problems of Army establishments and obtains their well data for study and preservation. Civilian geologists worked on water supplies for war needs in Latin American countries, West Indies and islands in Pacific. Early in emergency, Lt.Col. G. H. Taylor, appointed to act as liaison officer between Army and Geol. Survey re water supplies, prepd. section on ground water for Army water supply manual and helped select well drilling equip. for overseas use. Ten Geol. Survey men commissioned by Army to develop ground-water supplies. Several attached to gen. staffs of overseas armies or specially assigned. Rest in water supply battalions, one to each staff. Some effective in developing water supplies for troops immediately after landing in North Africa by driving and drilling wells.—*Ralph E. Noble.*

Army Camp Water Supply Systems. James Girand. Civ. Eng. **13:** 219 (May '43). Water requirements of theater-of-operations camps somewhat lower than those for mobilization type—about 70 gpd. per capita. Latest development in cantonments "field camp." Camps being designed for 50 gpd. per capita. Trend in airport design has followed same pattern as cantonments. Consumption depends on facilities available, weather and type of occupying troops. When housed in modern bldgs. with adequate facilities, consumption of water rises to 100 or 150 gpd. per capita. At one theater-of-operations camp, water and sewer systems governed site plan to unusual degree. Field-camp constr. introduced only recently. Dispersed-type air bases particularly interesting in that considerable ingenuity required for economic soln. of problem of furnishing small quant. of water over extremely large area. Extremely high stds. of constr. of early cantonments not justified.—*H. E. Babbitt.*

Water Supply for Army Camps and War Factories. Anon. The Engr. (Br.) **175:** 277 (Apr. 2, '43). Engr. Dept. of U.S. Army prepd. detailed instructions. Water consumption 100 gpd. per capita for camps of mobilization type; 70 in theater-of-operation type; 150 for permanent army posts; 35–50 per 8-hr. shift for industrial plants; 100 for resident personnel; 25 per animal. Where no wells exist in vicinity, test wells to be driven, preferably by rotary process. Filtration usually required of water from surface sources. Dual water systems permitted only for very special reasons. Fire service for large depots 4000 gpm. from 4 adjacent hydrants. Residual chlorine after sterilization of pipes and tanks 0.2 ppm.—*H. E. Babbitt.*

The Japanese Water Supply on the Airport at Guadalcanal. Richard D. Kirkpatrick. Mil. Engr. **35:** 276 (June '43). Author describes water supply layout as found at airport on Guadalcanal. Initial requisites were: (1) water pure enough for drinking after filtration through connected Shofu filters (*see* Jour. A.W.W.A. **35:** 626 ('43)) and (2) sufficient supply to soil-cement stabilization mixer, also connected. Deduces following facts re enemy's theory of water supply in the field: Simplicity in design paramount; permanency of installation expected; sanitation a minor factor; good equip. and materials plentiful, but careful planning conserves use. Noticeable that, by careful layout, Japs created water system utilizing terrain to fullest. Such mech. devices as pumps very limited. Possible great error in placing water tanks in exposed position on airport, always aircraft target. Constr. heavy, however, and chance of damage indeed small. Apparently important to Jap engrs. that airport landing strips have good maint. for which water required. Their system seems to tend toward gravity-head type rather than one in which head created by pumping, or even very simple procedure of tank truck filled some distance from place used.—*Ralph E. Noble.*

Army Water Testing Method Simplifies Chlorine Residual Check. Anon. Eng. News-Rec. **130:** 908 (June 17, '43). In collaboration with Med. Corps and several chem. companies, Quartermaster Corps developed ortho-tolidine in form of tablets equal to 1 ml. of test soln. Tablets packed in nested double tube, inner one of glass contg. 50 tablets and outer one of plastic serving as tube for conducting test. Outer tube has 0.75" transparent yellow band at top showing exact color water should have when tested after Cl treatment. Test performed by simply adding tablet to tube of treated water and allowing it to dissolve and then comparing color produced with colored band at top of tube. To facilitate entire operation of purifying water, package designed contg. 100 ampules of Ca hypochlorite and 2 tubes of ortho-tolidine tablets.—*R. E. Thompson.*

Contributions of the Medical Corps of the Army to the Public Health Laboratory. EDGAR E. HUME. Science **97**: 293 (Apr. 2, '43). Author reviews certain outstanding contributions to public health by the Army or its officers. Some of interest to water works profession. *Typhoid Fever Prophylaxis:* Maj. Walter Reed (1851–1902) best remembered for his epidemiologic studies of yellow fever. Almost as important were his studies of typhoid fever in Army camps during Spanish-Am. War (1898) showing disease transmitted not only by contamd. drinking water but also by direct contact. Between Spanish-Am. and World War, typhoid fever incidence reduced by troops immunization with vaccine following Sir Almroth Wright's (Roy. Army Med. Col., London) prophylaxis. U.S. Army first to adopt compulsory typhoid prophylaxis in '11. At outbreak of present war, Army Med. School mfrd. more than 2500 liters per yr., sufficient for million prophylaxes. This amt. now being exceeded. *Purification of Drinking Water:* No activity of modern pub. health lab. more important than examn. of water for potability. Brig. Gen. (then Maj.) Carl Rogers Darnall devised Darnall filter, ingenious adaptation of mech. filtration principles to field needs. Far more important was his introduction of liquid Cl for water purif. in '10. Specially woven, 30-gal. Lyster bag, for chlorination of water in field developed by Col. (then Maj.) Wm. J. L. Lyster. More recently, high-test hypochlorite adopted, being more stable and releasing more Cl. *Dysentery:* In 1900, Acting Asst. Surgeon (now Col., ret.) Charles F. Craig wrote of amebic dysentery observations in San Francisco hospital. At same time work begun on amebic and bacillary types in Phillipines by Asst. Surgeon (later Col.) Richard P. Strong and Dr. Wm. F. Musgrave. One dysentery type bears Strong's name. Other sections include: America's first bacteriologist, bacteriology of gunshot wounds, physiology of digestion, malaria, venereal disease control, lab. work in Puerto Rico in war on hookworm, pneumonia, trench fever, tropical diseases and warfare chem. agents.—*Ralph E. Noble.*

Emergency Medical Service in Industrial Plants. Med. Div. Bul. No. 7, OCD Publication 3061 (Jan. '43). Included in disaster operations plan is section on sanitation services. Dangers to plant and community sanitation inherent in disasters. Many indus. plants have independent water supplies of which some used for potable purposes. Explosions may fracture water mains and sewers leading to poln. of potable supply, or lowered water pressure during fire fighting may back-siphon sewage into latter. Integrity of water supply must be maintd. to permit fire fighting operations and minimize interruption of plant production. Special steps taken by state and local health and water officials to insure adequacy of pub. water supplies and maint. safe community sanitation stds. OCD assigned san. engrs. to each regional OCD to assist in developing program. State defense councils will supply copies of OCD buls: (1) Maint. of Pub. Water Supplies Under War Conditions and (2) Munic. Sanitation Under War Conditions. Plant should arrange with above officials to facilitate mutual assistance in disaster, providing for exchange of personnel and material to expedite repair and minimize damage, production interruption and danger to health of persons in plant and community.—*Ralph E. Noble.*

Occupational Deferment of Chemists and Chemical Engineers. CHARLES L. PARSONS. Chem. & Eng. News **21**: 1206 (July 25, '43). Amended data and recommendations explained. Selective Service System Activity and Occupation Bul. No. 35 directs that information from National Roster of Scientific and Specialized Personnel, to whom questions of deferment of chemists and chem. engrs. referred, be included in registrant's cover sheet by his Local Board. All teachers, students, graduate assts., chemists and chem. engrs. should register with National Roster, Com. on Chemists and Chem. Engrs., 10th & U Sts., N.W., Washington, D.C. National Roster will shortly re-contact scientific and specialized personnel with new form for registration. Industry faced with need of occupational deferment should obtain from National Headquarters, Selective Service System, bulletins which apply specifically. Where continued occupational deferment essential, employer should send notarized copy of registrant's Form 42A to National Roster with request that reliable information be sent to Local Board. Unemployed chemist, on receipt of reclassification from Local Board, may present own case to National Roster, who will communicate with Local Board. If registrant ordered for induction, inform National Roster for aid in retaining proper niche in war effort; Local Board may reopen case if error in judgment made. Employer and employee have

10 days, following reclassification, for appeal; if necessary, appeal should be carried to State Director or to President. When appeal first taken, transfer of case to Appeal Board where individual working can be made on request of registrant or employer; this step valuable to improve appreciation of Appeal Board of value of occupation. Where delivery for induction to distant Local Board hardship, inductee may request transfer to nearest Local Board on Form 154. Men between ages 18 to 25, single or married without children, need not be scheduled for replacement during 6 mo. deferment period provided they: (1) utilize highest skills or (2) demonstrate capac. for unusual attainment. Army and Navy no longer have place to utilize high skill and professional qualifications of these chemists and chem. engrs., their efforts should be conserved as key men in production front. Activity and Occupation Bul. No. 33–6, as amended, recommends to Local Boards deferment of students in chemistry and chem. eng. provided graduation expected within 24 mo.—*A. A. Hirsch.*

How to Protect Yourself Against War Gas. *OCD Operations Letter 128* (Supersedes Operations Letter 46). Chem. & Eng. News **21:** 1098 (July 10, '43). Following rules stated and explained: (1) stay indoors; (2) if outdoors, vacate gassed area; (3) act promptly to remove gas spots; (4) follow cleansing routine, and (5) obey air-raid warden. Discard contamd. shoes and clothing outside house. Flush eyes with ample water or sodium bicarbonate soln. Blot liquid off skin with paper or cloth, then sponge with sodium hypochlorite soln., cover with soap suds, rinse and dry by patting, not rubbing. Snuff or gargle sodium bicarbonate solution if nose or throat irritated. If smoking becomes distasteful lie prostrate awaiting physician.—*A. A. Hirsch.*

Protection From Poison Gas. ANON. Chem. & Eng. News **21:** 1101 (July 10, '43). Should enemy attack Am. cities with poison gas, identification of chems. assured. Civilian gas reconnaissance agents will collect samples, transfer them to Army Unit Gas Officers who transmit same to one of six strategically located labs. Liquid samples preferred; tightly closed wide-mouth glass jars recommended containers. Similar arrangements to identify incendiary bomb fragments.—*A. A. Hirsch.*

Emergency Water Supply Basins, Dams, etc. E. G. POWELL. Surveyor (Br.) **102:** 263 (June 25, '43). Areas in Merton and Morden dist. considered high fire risk. Some 200 yd. of 6″ steel pipe laid from river to tanks in eastern area to serve as pumping mains. Five sumps provided in watercourses. Approx. 70,000 gal. (Imp.) provided in small rectangular tanks of 5000–7000 gal. (Imp.) capac. Emergency water storage has been allocated to provide addnl. 210,000 gal. (Imp.) in brick and concrete circular tanks of 10,000-, 22,000- and 40,000-gal. (Imp.) capac. Sumps consist of 36″ diam. precast concrete tubes, 3′ in length, sunk into bed of watercourses adjacent to roadways.—*H. E. Babbitt.*

HYDROLOGY

Statistical Analysis in Hydrology. L. R. BEARD. Proc. A.S.C.E. **68:** 1077 (Sept. '42). In its application to flood-control work, duration curve may be looked upon as refinement of practice of basing design on largest flood of record. Theory of duration curve relatively simple. Future occurrences considered to constitute series arranged in order of descending magnitude. If infinite no. of occurrences in store, series may be represented by continuous curve. With curve defined, forecasts concerning future may be made. Curve may represent all of occurrences ever to happen or all of yearly max. occurrences ever to happen or any one of many other series. Since smooth curve obtained best possible representation of true duration curve and since curve independent of no. of occurrences used in constr., normal series comprising any no. of occurrences can be obtained from curve. Many attempts made to describe duration curve mathematically. Only Gauss-Laplace normal distr. curve has rigid math. derivation. One of advantages of design by duration curve rather than by max. occurrence of record is greater accuracy obtained. In design of flood protection structure, period for which structure is to afford protection chosen by economic anal. To protect dam against possible failure, would be ideal, if feasible, to design spillway for max. possible flood flows. Found, however, that this quant. so huge as to prohibit design. So-called max. probable flood can be detd. by use of duration

curve if degree of probability of occurrence within given period of time stipulated. *Conclusion:* (1) To represent best distr. curve using finite no. of occurrences, occurrences should not be plotted with equal spacing. (2) Plotting of series of occurrences above base value as complete series not mathematically rigorous. (3) Use of Gaussian normal distr. curve in no way proved inapplicable to properly chosen rainfall or runoff series. (4) Duration curve can be used to det. occurrence that probably will not be exceeded within given period, as well as occurrence which will be exceeded once within period. (5) "Max. probable" flood can be detd. by use of duration curve. *Discussion. Ibid.* **68**: 1458, 1661 (Oct., Nov. '42). L. Standish Hall: Theory of frequency distr. curve, on which duration curve based, predicated on certain assumptions: (1) no difference in essential respect between conditions and methods from which observations drawn; (2) conditions that regulate appearance of any event must be same for every series and for every observation in series; and (3) individual events must be completely independent of one another. First condition not fulfilled, since progressive improvement over period of available records with regard to stream-flow measurements. Satisfaction of second condition requires that no cyclic changes affect hydrologic records. Although climatic divisions of world appear to be const., known minor fluctuations having duration ranging from few yr. to many centuries. Third condition cannot be realized in hydrologic cycle, since climate continuous process, each event influenced by weather of preceding periods. Author's detn. of location of plotting position of each series of occurrences based on theoretical expression of binomial expansion as form of frequency distr. Some question in writer's mind as to propriety of this assumption. Author indicates Gauss-Laplace normal distr. curve only one having rigid mathematical derivation. Possible that many distributions, covering all types, may follow this law, but, in general, hydrologic data differ too greatly from it to make possible any forced agreement. Author states that "logarithmic transformation of variate often used with exceptional success." This assumes that geometric mean is true avg. of series and that logs follow normal law of error. Geometric mean of series always less than arithmetic mean and most hydrologic data have distr. with mode less than mean. Such data cannot possibly follow normal law of error. Discussion of accuracy of duration curve very valuable, but author does not explain method of detg. probable error and largest deviation to sufficient extent to indicate applicability of his results to other statistics. H. Alden Foster: Author states: "Largest occurrence in 10-yr. period considered to be median of largest occurrences of all 10-yr. periods ever to happen." In writer's opinion not correct. True that "probability that max. occurrence of set chosen at random will exceed median of max. occurrences of all sets is 50%." Probability that "none of 10 occurrences chosen at random will exceed median of max. occurrences of all sets," however, not 50% as stated by author. Seems obvious to writer that author's method of computing percentage of occurrence corresponding to median of max. occurrences from all of sets cannot be justified. Writer fully concurs in author's statement that "one of advantages of design by duration curve rather than by max. occurrence of record is that greater accuracy obtained." Paul V. Hodges: Author demonstrates that straight-line log curves fit rainfall records very well and that log of observations may be assumed to be normally distributed. Also shown that rainfall, runoff and flood occurrences may or may not indicate straight-line log curves and that various methods of developing curves are all valuable tools for use with different statistical characteristics. Also appears that straight-line log curve justified only in cases where it can be made to fit data without changing computed coef. of variation. Joe W. Johnson: In addn. to flood-control problems, application of principles of duration curve affords valuable aid in estg. avg. annual vol. of net load transported by streams. For low rates of flow, drainage basin characteristics, such as soil types, vegetal cover, tillage methods and stage of soil erosion, influence rate of runoff greatly. However, during periods when high rates of pptn. cause high runoff rates, drainage basin characteristics affect runoff very little. Fortunate condition in connection with bed-load problems that duration curves for streams in particular region identical for higher rates of flow, for during these flows greatest percentage of annual vol. of bed-load transported. Vol. of bed-load transported per unit of time for each discharge may be detd. either by suitable bed-load formula or by relationship between load and discharge established by

direct measurements on stream under investigation. Rate of transportation per unit of time for particular discharge, multiplied by total time discharge prevails per yr., gives annual vol. of bed-load. Sum of amts. for various discharges gives avg. annual vol. of sediment transported as bed-load. Author's anal. of duration curves of particular value in connection with application of duration curves to bed-load studies. *Ibid.* **68:** 1847 (Dec. '42). R. H. BLYTHE: Flood-frequency curves find their most justifiable use in soln. of economic problems, such as estn. of avg. annual damage, rather than in forecasting max. flood for design purposes. Curve fitted freehand to plotted points would seem to be logical method of expressing flood-frequency information contained in usual record of flood flows. To put problem simply and concretely, consider series of 20 occurrences. Max. observed occurrence in 1 sample of 20 is mode of distr. of extreme values in no. of samples of 20 observations. Possible to compute value of mode by:

$$\text{Mode} = \bar{x} - \sigma \left[\frac{\sqrt{\beta_1}(\beta_2 + 3)}{2(5\beta_2 - 6\beta_1 - 9)} \right]$$

in which $\bar{x}$ = mean, σ = std. deviation, β_1 = coef. of skewness and β_2 = coef. of kurtosis. *Ibid.* **69:** 299 (Feb. '43). R. W. DAVENPORT: Assuming that rare floods occur fortuitously, statistical theory affords means, through application of normal probability (binomial) distr., to compute theoretical distr. of 100-yr. floods among one hundred 100-yr. periods. Distr. of greatest floods for 100-yr. periods would be skew. Plotting position for single sample may conceivably be influenced by various practical considerations inherent in particular problem to which data applied. Principal value of method its fundamental soundness and its clarifying influence on reasoning and concepts, which influence may spread much beyond consideration of matter that may be immediately affected. EDWARD J. BEDNARSKI: At any stage in development of science there are events that are predictable and events that are not. This should not be lost from sight of hydrologists working as statisticians. No one can predict on basis of past records order of magnitude of flood that might occur in given locality this or next yr. "Probable max. flood" should be "so large that chance of its being exceeded no greater than hazards normal to all of man's activities." Tendency in gen. to accord preference to soln. of problem if soln. result of complicated, lengthy and tedious computations—carefully, numerically checked. Relief, therefore, to find simple description of new way to compute "plotting positions." RALPH W. POWELL: Seems desirable that references be included in discussion to other recent publications on this subject, such as those of Prof. E. J. Gumbel and Bradford F. Kimball, and to type of plotting paper for flood frequency studies based on former. *Ibid.* **69:** 995 (June '43). E. J. GUMBEL: Numerous observations on many streams have shown that distr. of flood discharges is skew. Distr. rises quickly to max.—most probable annual flood discharge, mode—and reduces slowly. From moment that idea of unlimited variables accepted and assumption made that distr. of daily discharges belongs to this type, no such thing as max. possible flood. Correction of observed frequencies important for all observations if no. small and, only for largest observations if no. of observations large. General correction, which holds for all distrs. and for any no. of observations does not exist. To obtain corrected frequencies theoretical distr. corresponding to observations must be known. —*H. E. Babbitt.*

Distribution Graphs of Suspended Matter Concentration. JOE W. JOHNSON. Proc. A.S.C.E. **68:** 1383 (Oct. '42). With exception of dissolved matter, total solids load passing particular cross-section in stream may be classified as bed-material load or wash load, with definite grain size representing division between two classes. Particular grain size that divides sediment load into these two classes varies in different streams and, generally, throughout length of particular stream. In small flashy streams, almost all annual load of wash material carried during few days out of year and content of wash material may vary many hundred per cent within period of 1 hr. during rising and falling stage of stream. Load of fine material in stream appears to have main source, not in stream bed, but in other parts of drainage basin. Numerous investigations of soil loss and runoff from relatively small agric. plots give general information on principles underlying supply of erosional debris. Studies have shown, in general, that sediment concn. in runoff water from plot usually increases to max. within very short time, then decreases as duration of application of water continues, approaching

const. min. value asymptotically. From consideration that surface runoff and suspended-matter concn. appear to be related to same factors, investigation made of sediment-load studies to det. if any such relationship actually existed in natural stream. Concluded that: (1) By using distr. graph of suspended-matter concn. in connection with observed hydrograph and single observed suspended-matter concn., total suspended load of fine material transported during particular stream rise can be calcd. with reasonable accuracy. Previous records necessary in developing set of distr. graphs for particular location. (2) Although shape of distr. graph depends on period of rise and, to some extent, on intensity of rainfall, unless considerable basic data available to define effect of intensity adequately, avg. distr. graph for various periods of rise should be used. *Discussion. Ibid.* **69:** 321 (Feb. '43). H. A. EINSTEIN: Paper shows more clearly than ever necessity of dividing sediment load of stream into bed-material load and wash load. Concept of time-of-lead is time interval between max. concn. and max. discharge. In small watersheds this time-of-lead, as created in field, can be found in any section of watershed, since mere addn. of sediment loads and discharges will not materially affect time interval. Changes of discharge travel with wave veloc. which is considerably higher than flow veloc. in most streams. This fact sometimes enables max. of discharge to overtake max. concn. Logic of applying unit-graph method to large rivers problematical. In practical application of unit-graph method as proposed by author, application to streams with small and uniform watersheds proved to give good results with min. of cost. Applicability to streams with large and complex watersheds seems questionable and for this reason needs further study. *Ibid.* **69:** 571 (Apr. '43). G. C. DOBSON: No definite relation can be found between discharge and load of suspended sediment. Stream rarely, if ever, transports suspended matter to its capac. Not demonstrated that stream has definite transporting capac. Large part of sediment entering reservoir during flood composed of particles that had traveled from points where they entered stream channel to reservoir in one continuous journey. Any measures that would prevent fine sediment wash load from entering river system would be very efficient and immediate in effect. Rather prevalent belief that because of enormous amt. of sediment now in river channels, preventive measures would become effective only after long period of time. THOMAS R. CAMP: Since fine silt from farm land of interest in conservation program, it should be measured. Entire process of transportation, both on bed and in suspension, depends for its continuance upon scour from bed. No such thing as transportation in suspension, as such, for particles whose density differs from that of water. Little information available on total transport capac. of stream.—*H. E. Babbitt.*

Evaporation Loss From Land Areas. DAVID LLOYD. Wtr. & Wtr. Eng. (Br.) **44:** 135 (June '42). (*Abstracted,* Jour. A.W.W.A. **34:** 1476 ('42).) *Discussion. Ibid.* **45:** 60, 216 (Aug., Dec. '42). D. HALTON THOMSON: Engrs. must accept guidance by statisticians without necessarily comprehending processes by which they arrive at results. Useful to calc., from author's formula, effect of: (1) amt. of rainfall, (2) temp., (3) sunshine, (4) humidity, and (5) geol. formation, in different parts of Great Britain. Troublesome item is addnl. allowance to be made for ground-water evapn. loss based on geol. formation. Two types of evapn. loss might be combined in one formula by adding geol. term (say $+G$) to author's formula. J. KENNARD: Author has evolved method of estg. loss on catchment area which gives closer approxs. than method suggested by Committee of Inst. of Water Engrs. in '35. If author's research to be of value, desired to know what variations in avg. air temp. and hours of sunshine to be expected in particular area when rainfall less than long-period avg. Effect of shape and slope of catchment area apparently neglected. Extent of drainage area covered by water, particularly when large reservoir contemplated, must also have bearing on amt. of evapn. CHARLES LAPWORTH: Author makes use of data obtained from percolation gages as check on results obtained from natural gathering grounds. As conditions entirely dissimilar, correspondence in values purely fortuitous. Author's description of geol. strata appears too wide. Thus, ground loss for Cretaceous given as 8″ per annum. Cretaceous includes chalk, which is highly pervious, and Gault clay, likely to have ground-water loss similar to impervious Vyrnwy catchment of Silurian system. Doubtful if formula given can properly be applied to some chalk gathering grounds. Importance of paper lies in fact that foundation laid for

proper study of evapn. loss on scientific basis. *Author's Closure:* Behavior of flowing water in zone of aeration in ground differs from that in zone of satn. so use of word "percolation" limited to situation where water is in any zone of satn. In passage of water from rain, through ground, loss occurs by evapn. from upper soil, and where ground water within 8′ of air-soil surface, water can be drawn upward to be evapd. In dealing with estn. of supplies to underground sources, deduction from rainfall of surface flow and soil-water evapn. only. As to formula for total loss (*see* Jour. A.W.W.A. **34:** 1477 ('42), several successful comparisons made. Used in most favorable application with long-period avg. conditions and validity only impaired by change of value in excluding controlling factors. Query arises—Do percolation gages show soil-water evapn. or soil-water evapn. plus ground-water evapn? Detd. by constr. Evapn. gage for soil carrying vegetation should be not less than 20″ deep nor over 8′ deep and percolating gage should be about 6′ deep, with arrangements for drainage to collect at base, thus simulating soil-water and ground-water evapn. Author does not discard evidence of *all* percolation gages and cannot agree with Lapworth that correspondence between drainage from percolation gage and from large drainage area "purely fortuitous."—*H. E. Babbitt.*

Primary Role of Meteorology in Flood-Flow Estimating. Merrill Bernard. Proc. A.S.C.E. **69:** 105 (Jan. '43). Meteorology must play increasingly important role in eng. planning. Storm rainfall can be converted into flood flow in rational and realistic manner. Meteorologist interested in "hydrologic storm," which expressed results of his anal. "Meteorologic storm" is 3-dimensional phenomenon of considerably greater extent than "hydrologic" or "rain" storm. Beginning with general atmospheric disturbance of nationwide proportions, engr.-hydrologist moves progressively through extensive area of general pptn. to concns. of rainfall of basin-wide extent. There assumes responsibility for routing flood water over ground as surface runoff and through channel system as flood wave. Following classifications describe basic actions which produce storm rainfall: (1) quasi-stationary front with active minor waves; (2) rapidly developing waves along cold front; (3) major occluded cyclonic systems; (4) tropical cyclones; (5) local or frontal thunderstorms. Region of meteorol. homogeneity defined as one in which storm entering region can center over any point with equal probability. 21 such areas in U.S. defined. Max. possible storm limited to that type which can produce greatest amt. of rainfall over selected basin within critical period fixed by concn. time for basin and under conditions opt. for max. snow melt and min. infiltration and retardation. Factors other than rainfall, such as melting snow, infiltration rates and basin characteristics, enter into detn. of max. flood stage. Storm transposition not new idea. Comparatively simple to place isohyetal map in critical position over that of basin and convert rainfall into flood wave at selected point. To det. theoretically max. possible pptn. over area, necessary to develop equation of flow. Flow equation for typical area is:

$$R = \int KvW_e\,dt$$

in which K is coef. depending on basin characteristics; v is wind velocity, in mph.; W_e is effective precipitable water, in in.; and t is time, in hr. Pptn. as snow acquires signif. as flood hazard when it accumulates over basin beyond normal depth and water content. Intensive study for 4 yr. disclosed no method for detg. max. possible storm rainfall applying consistently to all basins. To present quant. results of storm transposition in suitable form for predicting max. possible flood, use made of procedure involving duration-depth curve. Realized that no statistical approach can provide valid adjustment for Type 1 storms occurring near Cincinnati and transposed to Pittsburgh area. In orientation of isohyetal patterns resulting from Type 1 storms must be emphasized that such storms occur with upper-air currents from west-southwest or southwest and that rainfall must necessarily take place along band at right-angles to major axis of Pittsburgh basin. Max. contribution to snow melt will result from combination of max. melting rates, max. storage of free water in snow and uniformly deep snow over basin. Increments of max. possible rainfall now combined with snow melt to form synthetic max. possible storm. Engr. not prepd. to deal adequately with pptn. until he has working knowledge of processes which take from sea, transport and ppt. over land myriad raindrops constituting great storm. *Discussion. Ibid.* **69:** 443 (Mar. '43). Edgar Dow Gilman:

From study of Ohio R. flood records appear to be 2 factors in floods regarding which more data and study would be enlightening: (1) variation in longitudinal profiles of flood flow and crests; (2) effect on such profiles of "timing" of tributary crests at their outlets relative to moving crest in river. That all tributaries to river should release their max. discharge at exact time to produce greatest increase in height of crest of major river as it passed mouth of each tributary might be equivalent to assuming improbable, if not impossible, series of cumulative coincidences. Floods in major rivers vary in height as more or fewer of total no. of tributaries approach corresponding timings in their discharge. In other words, cannot be stated that greatest pptn. will necessarily produce greatest floods. *Ibid.* **69:** 597 (Apr. '43). Clarence S. Jarvis: Solar radiation may contribute directly to heating of atmosphere through which it passes—probably somewhat less than 10% for clear, dry air when sun near zenith, but correspondingly more as rays become more inclined. Author and other writers assume that containing in atmospheric column covering globe is single inch of water, on avg. with appropriate excess in torrid regions and deficiency near poles. Record that more than 1″ fell at Cincinnati in hr. extending somewhat beyond midnight of March 25–26, '13; and considerable areas recorded as high as 6″ in 24 hr. Would have required more horizontal wind movement than recorded to account for 7 complete displacements and renewals of air columns over those extensive areas of high rainfall. Rainfall-runoff relationship simple. One important key to its soln., "unit hydrograph" seems destined to stand as monument to organized research. Writer found some consistent relationships between rainfall and runoff excess or deficiency, yr. by yr., from 1885 to 1914, inclusive, (in semi-arid Southwest). Ivan E. Houk: Occurrence of max. possible storm on given drainage area does not necessarily mean occurrence of max. possible flood, even though duration of storm rainfall may equal time of concn. for area. Probably would never be economically advisable to design bridges, culverts, sewers, spillways or other hydraulic structures for intense rates of runoff which max. pptn. would produce. L. R. Beard: Because of value of resolving variable into its more fundamental components, advantageous to deal with meteorological factors rather than with observed pptn. In replacing gen. function such as flood flow by its several component functions, primarily necessary to relate various component functions properly. Runoff-coef. function may converge more rapidly than does runoff function, for which reason questionable whether max. possible runoff can be detd. more accurately from rainfall than from runoff. Important point to be made is that possibility of evaluating one factor accurately should not be interpreted to mean that combined result necessarily evaluated accurately. Spillway and other designs sometimes based on max. possible or max. probable flood. 1 example of remote possibility ordinarily neglected is extreme condition of snow melt. Partly melted snow could exist as slush in such state that small amt. of heat would release tremendous quants. of water. *Ibid.* **69:** 1006 (June '43). Robert E. Kennedy: Background of approach to problem is to divide it into 3 parts: (1) there is max. amt. of moisture available for pptn. that can be brought to region under consideration; (2) there is max. wind veloc. in region that will feed moisture into storm vortex; and (3) there is max. time limit of duration of disturbance. First step is comparatively simple. In '39, Solot outlined method of ascertaining water in column 1 sq.in. in area and some miles high. Showalter and Solot outlined briefly procedure involved to est. geostrophic wind veloc. at that el. Third and final step is to est. how long storm will last. Resort made largely to statistical procedure of hydrologist in which depth of pptn., in in., plotted against duration in time. L. K. Sherman: Writer of opinion that: (1) Author's "design storm" is what it purports to be—"max. possible storm"; (2) it should be used in design of all structures which, in event of failure, would involve large loss of life and property damage; (3) values for runoff thus derived call for no addnl. factor of safety, since that factor has been cared for by concatination of possible events; and (4) author's "design storm" furnishes far more reliable limits than any data derived by statistical anal. Latter, based on long-time record, does furnish possible check on engr.'s computations and may aid him in deciding whether particular structure warrants elimn. of certain remote hazards.—*H. E. Babbitt.*

A Simple Method of Estimating Flood Frequency. Ralph W. Powell. Civ. Eng. **13:** 105 (Feb. '43). By purely logical reasoning Prof. Gumbel shows that:

$$Q_m = Q_a + S(0.7797y - 0.45005)$$

and

$$y = -\log_e\left[-\log_e\left(1 - \frac{1}{T}\right)\right],$$

where Q_m = flood equaled or exceeded on avg. of once in T yr.; Q_a = avg. of annual floods; S = std. deviation of annual floods

$$= \sqrt{\frac{n}{n-1}\left(\frac{\Sigma Q^2}{n} - Q_a^2\right)};$$

y = function of stream flow defined by preceding equations; n = no. of yr. of record; Q^2 = sum of squares of observed annual floods. If plotting paper prepd. on which horizontal lines spaced uniformly and distance between vertical lines made proportional to values of y, relationship between Q_m and T will plot as straight line. Any statistical est. based on short record untrustworthy, while long record will probably include old records less accurate than recent ones. Now that so many rivers subject to artificial regulation, data on former unregulated flow must not be mixed with figs. for regulated flow.—*H. E. Babbitt.*

A Method for Determining the Velocity of Runoff Water. A. W. Cooper & J. H. Neal. Agric. Eng. **23:** 385 (Dec. '42). Reports procedure and prelim. results of detg. overland flow veloc. Field equip. consisted of 2 large tilting plots 50′ × 15′. Each carried watertight 12″ deep sheet metal bin filled with 10″ Decatur clay loam soil. Cable and drum mechanism facilitated tilting of plots to any desired slope up to 30%. Plots equipped with type F artificial rainfall app. Electrolytic method used to det. increment velocs. of overland flow down plot slope. Electrolytic cells, spaced at 5′ intervals down slope, connected in series with milliammeters. NaCl introduced to plot top from sheet metal trough. As NaCl touched surface of runoff water, stopwatch started. As it reached cells, milliammeter needles deflected. Milliammeter and stopwatch readings photographed. Time of first milliammeter deflection used to calc. max. veloc., and time of max. deflection used to calc. mean veloc. Results show probable trends. In gen., veloc. of sheet or overland flow of water increased with deg. and length of slope. After rills formed in Decatur clay loam, however, flow veloc. became erratic and increased or decreased according to whether water was flowing in rills or had spread out. As yet, correlation of runoff water flow veloc. with soil losses not attempted because latter decreased with length of rainfall application. Tests on slopes run consecutively without stopping rainfall.—*Ralph E. Noble.*

Anthracite Flood. R. Dawson Hall. Coal Age **47:** 11: 66 (Nov. '42). Suggests need for better stream control. Glacial drift or loose material may aggravate sudden floods by blocking watercourses. Encroachment on channels, improper bridges, etc., add to problem. Remedies include watershed study and proper patrol.—*Ralph E. Noble.*

Rainfall in New England. George V. White. J.N.E.W.W.A. **56:** 405 (Dec. '42). Paper represents continuation of previous papers on same subject appearing in '15, '21, '26 and '30. Max. and min. monthly and yearly rainfalls and their yr. of occurrence given for each station prior to '29; present tables contain mo. rainfall for each yr., '29 through '41; at end of '38 and avg. given for recorded data up to that date. At present 108 stations have records covering period of 28 yr. or longer, in '13 only 45 stations had records of 25 yr. or more. Paper contains records of 285 stations. For complete information, report for '30 must be at hand with present paper. Tables of pptn. for following river watersheds also given: Charles R., Deerfield R. above Charlemont, Hoosatonic in Mass., Ipswich, Millers R., Nashua (South Branch), Sudbury, Swift and Ware.—*Martin E. Flentje.*

Report of the Committee on Floods. J. Boston Soc. Civ. Engrs. **29:** *Sec. 2*: 1 (Jan. '42). Disastrous floods occurred in New England in Nov. '27, Mar. '36 and Sept. '38. First caused by single severe rainstorm, second by rainfall plus melting snow, third by coastal hurricane. Normally, storms generate in tropics and condense over New England. Rivers in area vary in runoff, but highest flow that on White R. (tributary to Conn. R.) which reached peak of 120,000 cfs. from 690 sq.mi., or 174 cfs./sq.mi., in Nov. '27 on Conn. R. shed. Central Vt. had greatest floods in '27 and Mass. and Conn. in '38, but '36 flood greatest on river, e.g., in '38, rains of 17″ in 5 days recorded at different locations. Studies indicate that pptn. (and floods) might exceed recent storms by 15–30%. Water content of snow on ground Mar. 9, '36, 2–10″,

avgg. about 5″ in Conn. Valley. 4 storm centers passed from Mar. 9 to Mar. 22, '36. Total rainfall over 18″ in one small area, but 4–6″ over most of section. Added to snowfall this made record. Flood of '38 most disastrous. Rainfall preceded hurricane. Max. nearly 20″ and much over 11″. On Conn. R., flow 29.9 cfs./sq.mi. in '36 and 24.0 cfs./sq.mi. in '38. Runoffs 11.18″ and 4.05″, resp., and percentages collected 88 and 56. Storage in reservoirs reduced peak flows materially, reaching 100% in some instances with fairly large drainage areas. Sept. '30 Rpt. of Com. on Floods derived formula $Q = C_f R \sqrt{A}$; where Q is flow, in cfs.; C_f is coef. of flow; R is runoff, in in.; A is drainage area, in sq.mi. Unit hydrograph and distr. graph proved useful. Flood of Mar. '36 gave total of 10–12″ runoff, but equiv. concd. storm runoff was 5.5–6.0″. 8″ flood may be possible. Flood curves extensively developed and are useful, but results may be considerably in error unless coef. included for each point on river. Flood performance may be predicted by prescribed methods of calcn. Spillway capacs. would exceed present constr. if adequately designed. Encroachments particularly must be watched. Rainfall varies at times with el., but not all storms show such variation. Snowfall increases materially with altitude. Effect of air temp. on snow runoff to show melting at various temps. above 27°F., usually being about 0.017″ per deg.-day. Max. avg. daily runoff from snow, when accompanied by rain, about 2″. Flood of '36 estd. by some methods as having 300–500-yr. frequency, but most likely nearly 1000 yr. Statistical methods present difficulties. Extreme variations between 98-yr. records prior to '36 and records since show fallacy of some computations. Direct losses in Conn. R. valley totaled nearly $70,000,000 for 3 floods; indirect losses about $75,000,000. Represented $3000 and $6000 loss resp., per sq.mi. Recurring losses generally decrease with each flood. Depn. may be used as measure of flood losses. Avg. annual losses and benefits may be compared to det. value of any particular flood control project. Water supplies affected, particularly in '36. Loss only fraction of total losses. Freedom from communicable diseases marked because of prompt action in using sterilizing equip. Work started on several flood control reservoirs by U.S. Engr. Corps. Channel improvements carried out in several locations. Both state and federal funds used, latter particularly on bridges. Many roads and water works being changed. Flood forecasting carried out by U.S. Weather Bureau. Daily and 6-hr. periods used. If more than 1″ falls in 6 hr., telegrams dispatched. Daily river stages recorded. Telephone and radio employed. Disaster and other committees well organized and satisfactory. Pa. warning system not needed in New England.—*Charles H. Capen.*

IRRIGATION AND CONSERVATION

Water Prospects Bright for 1943. ANON. Western Constr. News **18:** 219 (May '43). Unquestionably good water year indicated for Bureau of Reclamation power and irrigation projects in West, according to snow surveys in drainage basins of western streams feeding Bureau's reservoirs supplying area's food and hydroelec. energy. In some basins, runoff quarter century greatest. Bureau's 61,600,000 acre-ft. storage capac., including Boulder and Grand Coulee Dams, more than 70% of total available for power and irrigation in West. With runoff expected to equal or exceed record yr., Columbia R. supplies Grand Coulee and Bonneville power plants serving aluminum plants producing more than ¼ natl. output. Supplying heavy crop producer Yakima food project, Yakima R. may reach 24-yr. peak. Snows 50% heavier in Umatilla R. feeding Umatilla project in northern Oregon. Clark Fork in western Mont., discharging into Columbia R., 57% above avg. and supplies Bitter Root and Frenchtown development. Water content of snow along Upper Snake R. and tributaries Owyhee, Boise and Payette, highest in 25 yr. Serve Minidoka and Boise projects, including power production in Idaho, and Owyhee, Vale and Burnt R. projects in Ore. Runoff of Missouri R. and tributaries will be much above normal. Snow cover on Yellowstone R. more than double of year ago, while Mill R. ⅓ more. These supply Riverton and Shoshone (Wyo.), Buford- Trenton (N.D.), Belle Fourche (S.D.), and Sun R., Milk R., Huntley, Buffalo Rapids and Lower Yellowstone projects (Mont.). Outlook very favorable for runoff of N. Platte R. and tributaries from which N. Platte(Neb.-Wyo.) project supplied for power and irrigation; and Kendrick (Wyo.) project for power.

N. Platte reservoirs contain largest carry-over since '29. Elephant Butte Reservoir on Rio Grande R. full at start of irrigation season. Serves Rio Grande project (N.M.-Tex.) producing food crops, cotton and power. On Pecos R., serving Carlsbad development (N.M.), snow cover *less* than year ago (*see* following abstract). Water content of snow on headwaters of Colorado R. above Grand Jct. 20% greater than last yr. In tributary Green R. headwaters, content 2½ times that of '42. Gunnison R. runoff, serving Uncompahgre project (Colo.), about avg. Grand Valley (Colo.) irrigation-power project served by diversions from the Colorado. Moon Lake, Strawberry Valley and Sanpete irrigation projects (Utah) served by Colo. R. tributaries with fair runoff indicated. Expected above avg. runoff in Colo. R. headwaters important in power and food production in Pacif. S.W. Lake Mead, largest storage reservoir in world, feeds from Colo. R. and supplies Boulder power plant, world's largest, providing power to Nev. and Calif. war indus. Water releases from Boulder dam also produce power at Parker Dam on Yuma (Ariz.) project, and assure adequate supply for highly productive areas of Imperial Valley (Calif.) and Yuma Valley (Ariz.). Reservoir carry-over of Salt and Verde R's. (Ariz.) supplying Salt R. Reclamation project may compensate for *deficient* snow coverage in headwaters. In any event, power from Parker Dam and standby plants will protect area's power needs. Accumulative pptn. in northern Utah assures abundant water in '43 for projects served by Hyrum, Ogden and Weber R's. 57% increase over last yr. expected in Klamath Lake Basin runoff, benefiting Klamath project (Ore.-Calif.), outstanding potato area. *Calif. Report:* Calif. Water Resources Div. bul. contains main snow survey measurements at every snow course in state, and forecasts of runoff, low water, and delta salinity concns. March pptn. above normal over most of Sierra Nevada, considerably increasing snow pack during Apr. Good water yr. expected, with ample supply to operate all installed hydro-elec. generating facilities, and surplus over irrigation, indus., munic. and domestic use. Water will again flow into Tulare Lake from Kings, Kaweah and Kern R's. as unregulated discharge during snow-melt season promises to exceed normal agric. area demand. South of Tehachapi Mts. pptn. to date relatively heavier. Los Angeles area reports pptn. 175% of normal; San Gabriel, 170%; Santa Ana, 135%; and Pacif. Slope Basins of San Diego county, 90%. Runoffs of Sierra streams from Apr. 1 to July 31 to range from 88% of normal for Pit R. to 124% for Kern R. Flows for Sacramento, Feather, American and San Joaquin R's. estd. Salinity penetration into rivers and sloughs of delta region light. Saline concns. to a deg. dangerous for growing crops, not expected to extend beyond Emmaton on Sacramento and Jersey on San Joaquin R's.—*Ralph E. Noble.*

The Pecos River Joint Investigation in the Pecos River Basin in New Mexico and Texas. (X) Natl. Resources Planning Bd. (June '42). Essential water problem of Pecos R. basin is division of water supply between upper and middle basins of N.M. and lower one of Tex., considering past and present uses and requirements to future development. Elements also involved: salvage of recoverable wastes, amelioration of salinity conditions, provision for flood, erosion and sedimentation control. Major problem in N.M. is maintg. adequate quant. and qual. of water supply for irrigation of Carlsbad project lands. Same true in Tex. for irrigating lands under Red Bluff water power control dist. where salinity control especially acute. Constr. of Alamogordo Reservoir for Carlsbad project opposed by Tex., fearing retention of flood waters which would otherwise replenish Red Bluff Reservoir storage for Tex. lands. Indicated measures to ameliorate saline conditions in Pecos R. Valley are: (1) Reduction of river's salt load by watershed conservation to control erosion and lessen salt-carrying silt load entering river; also diversion and disposal of small vol. inflows to river of highly concd. waters. (2) Changes in points of river diversion from lower to higher locations to utilize only upper, less concd. water, particularly applicable between Red Bluff and Girvin. (3) Provision for adequate root-zone and subsoil drainage. (4) Adjustments to utilize best lands in locations where irrigated lands unproductive because of salt accumulations and drainage lack. Measure used successfully on Carlsbad project and now applicable in valley between Red Bluff and Girvin. (5) Applying greater water quants. in irrigation so that, with adequate subsoil drainage, salts will be leached from root zone and tolerable soil soln. concns. maintd. Avg. soil soln. concn. not exceeding 24 tons/acre-ft. best represents required condition in Red Bluff dists. to assure reasonable min. crop damage from salinity. Irrigation constitutes prac-

tically entire water use in Pecos R. basin. Use by cities, towns and villages relatively minor; for power purposes, small and nonconsumptive; for recreational and wild life, important but nonconsumptive. In 45 yr. service, McMillan reservoir accumulated 51,250 acre-ft. of sediment, thereby losing 57% of original capac. Tentative report of Bd. of Engrs. for Rivers and Harbors recommended: (1) conditional constr. of diversion plan to protect Roswell, N.M.; (2) conditional constr. of levees to protect Pecos, Tex.; and (3) that no part of total cost of Alamogordo Dam and Reservoir on Pecos R., N.M., be allocated to flood control. Availability and use under 6 conditions described.—*Ralph E. Noble.*

The Conservation of Natural Resources With Some Reference to Postwar Planning. *A Symposium.* Eng. Jour. (Can.) **25:** 663 (Dec. '42). *Introduction.* ROBERT F. LEGGET: No approach to proper husbanding of resources can be made without some consideration of water. Depletion of forests interferes with runoff conditions. Natural consequence is alteration of normal river flow. *Forest and Drainage Areas of Ontario.* F. A. MACDOUGALL: Would be unwise to generalize as to relationship of forest to water in all province. Function of Laurentian Shield forest one of preventing evapn. by sheltering area, encouraging pptn. and acting as filter to let water seep out gradually. *Water Situation in Southern Ontario.* A. F. COVENTRY: Several recent investigations confirmed doubts and given point to fears for stability of water supply of southern Ont. First of researches conducted in '37 in King Twp. 80 to 85% of streams found becoming waterless, wells failing and springs and ponds drying up. In 15 Twps. of Grey County 75% of streams have ceased to flow. Survey of streams of Peel Plain region, west of Toronto, reveals conditions closely comparable to those of King Twp. Dominant feature of existing water situation in southern Ont. are floods in Spring thaw; dry stream beds in summer, failing wells in fall and winter. All these assignable to same cause—removal of too much of original cover, mainly forests. Ont. faced with grave problem which, left unsolved, threatens her future, both social and economic. *Public Health and Conservation.* A. E. BERRY: Ont. fortunate in having adequate supply of water for domestic purposes except in small streams and shallow wells. Poln. major problem in built-up communities.—*H. E. Babbitt.*

Demarcation of Drought Areas and Its Uses. W. R. BALDWIN-WISEMAN. Australian Surveyor (Mar. 2, '42). While communal existence owed origin to water shortage, only in recent years have communities paid any attention to study of hydro-economics, necessary for effective control of water and systematic counteraction of drought. Years ago G. J. Symons suggested that "engr.'s drought" operative at any rain-gaging station when for 3 mo. or more deficiency of rainfall from mean rainfall of that period 50% or more. Anal. of meteorological and allied data directed toward production of: (1) isodef charts; (2) isoagdef charts; (3) isodrisk charts; (4) line charts; (5) residual mass curves of monthly rainfall, evapn., percolation and runoff; (6) time-percentage deficiency charts. Isodef charts show lines of equal percentage deficiency from mean rainfall. Isoagdef charts show lines of equal aggregate percentage deficiency from mean rainfall. Isodrisk charts, or equal percentage risk charts, prepd. in manner similar to isoagdef charts by plotting against station the value of its drought index, which is sum of drought factors at that station, for each month of growing season of specific crop. Line charts graphically present incidence of drought throughout area during any prolonged visitation. Residual mass curves of rainfall, streamflow and percolation afford clear indication of march of rainfall at station, steeper slopes of ascending or descending curves indicating wetter or drier periods. Time-percentage deficiency chart, supplementary to residual mass curve at station, of use in investigating varying severity of major drought at that station or comparing relative severity of drought at two or more stations. Economic development of any region necessitates that every measure be taken to elim. losses of magnitude of drought losses. Isodef charts afford valuable information as to location and extent of drought-free areas within or contiguous to an extensive area of recurrent drought. Researches demonstrate pulse in drought recurrence, droughts being frequently recurrent at intervals of about 640 yr. with wetter conditions in intermediate period. Probability of recurrence about A.D. 2010.—*H. E. Babbitt.*

The Nitrogen Content of Ceylon Rain. D. E. V. KOCH. Trop. Agr. (Ceylon) **97:** 74 ('41). Data over period of 1 yr. on amt. of ammonia, nitrate and nitrite N in rain showed that highest amts. of N brought down with

fairly heavy rainfall after period of drought. N content of rain as detd. on semi-monthly collections depended on extent to which matter in atm. previously washed out by rain, total quant. of fall and intensity of thunderstorms accompanying rainfall. Annual rainfall 118.04" and contained 7.490 lb. N as ammonia and 5.359 lb. as nitrate and nitrite per acre. Amt. N available to plants less in proportion to extent of runoff.—*C.A.*

Unusual Events and Their Relation to Federal Water Policies. W. G. Hoyt. Proc. A.S.C.E. **68:** 211 (Feb. '42) (*Abstracted,* Jour. A.W.W.A. **34:** 1580 ('42).) *Discussion. Ibid.* **68:** 619, 1199 (Apr., Sept. '42). Edward H. Sargent: Writer feels that success of Scandaga Reservoir in achieving multiple purposes contributed to changing of current eng. opinion regarding such functioning. Dana M. Wood: At least two other papers should be read along with this one to clarify broad background for present fed. water policies. In '38, James L. Fly presented legal development of fed. policies. David E. Lilenthal and Robert H. Marquis, in '41, emphasized expansion of govtl. activities for admin. and development of multiple-purpose projects. Important effect of broadening fed. water policies with respect to both droughts and floods to lessen damages by adequate planning on large scale. One problem that will offer increasing difficulties in solution that of co-ordinating work of various fed. agencies engaged on water control and development. James S. Sweet: Throughout paper, author mentions various govt. depts. in which hydraulic or hydrologic activities exist. To layman, fact gives reason to believe all activities are, or could be, co-ordinated. Placement of all hydrologic activities in one bureau would be impracticable. As alternative, creation of hydraulic co-ordinating joint committee seems feasible. J. L. Campbell: Fed. water policies developed since '30 constitute one phase of course of fed. govt. away from that Am. way of life which rests on and is sustained by private initiative and enterprise. Those who support continuance of such allege that projects are necessary to war program because of hydroelec. power which they would provide. Is there such lack of patriotism that pet schemes dressed in guise of war need are delaying and crippling war effort? Of course, America must move forward; but she should so move in right way, under Bill of Rights in charter of Am. liberty. Under fed. water policies, there is horn of plenty of "unusual events." David J. Guy: Without oversimplification author has isolated germs of revolution taking place in policy of U.S. with respect to water resources. Reader, however, requires fuller historical background. Subject of natl. water policy calls for more extensive plotting of points and circumstances before anyone can indicate trend with confidence. Current water policy enmeshed in "shelf of projects" that has been built up awaiting "go" sign when jobs are needed after war ends. Extension of fed. water policy does not stop at planning. Being projected into fields of operation and management, prompted, at times, by political rather than eng. considerations. "Multiple-use projects" has become slogan which has political as well as eng. significance. Natl. water policies in regard to both practice and planning, should be based on economic and eng. facts and should be free of such (political) issues. Albert S. Fry: Great flood of '27 really demonstrated that flood control natl. problem far too big for local interests even in good times. Creation of TVA marked not only inception of multiple-use project by fed. govt., but also created complete watershed development project with all phases of development under one fed. agency. Beneficial result of recent fed. water policies development of closer co-operation between various govt. agencies concerned with water projects and recognition of interrelationship of interests of several agencies in specific problems. Another example of co-operative relationship is that between Weather Bureau and TVA with respect to weather forecasting. *Ibid.* **69:** 148 ('43). *Author's Closure:* Water policies, at any one time, have depended in some immeasurable deg. on climatic, economic and social circumstances. When conditions change, policies respond. From viewpoint of peacetime, no one can yet say positively whether projects generally worth cost. Future policy makers must decide whether or not best objectives will be accomplished by following advisory leadership of Water Resources Com. of NRPB or whether similar com. should be vested with sufficient authority to co-ordinate and direct future water policies. In other words, should there be nation-wide group of authorities similar to TVA, or should developments for irrigation, power, flood control and land-use continue to be administered by separate organizations, federal or state, policies of which fixed by law, or combination of both?—*H. E. Babbitt.*

Emergency Alternate Provisions to A.W.W.A. Steel Pipe Specifications

As the field knows, A.W.W.A. Committee 7A has long been at work on emergency alternate provisions for wartime standardization of steel pipe. That Committee has developed emergency alternate provisions which formed the basis for detailed consideration by the A.W.W.A. Board of Directors during the Cleveland Conference. In line with the instructions of the Board developed at that time, these Emergency Alternate Provisions were promulgated for 7A.3–1940 as of July 24, 1943, and for 7A.4–1941–TR as of June 19, 1943.

These Emergency Alternate Provisions are issued in the interest of expediting procurement or conserving materials during the period of National Emergency. They affect only the requirements and specific sections of the specifications referred to in the provisions published below.

The War Production Board, on August 31, 1943, issued Limitation Order L–211, Schedule 13, which sets up specifications for steel pipe as used in water works. The net effect of this schedule is to reduce by about 65 per cent the number of sizes and thicknesses shown in the various pipe mill catalogs. In Note 4 of List 1 of Schedule 13, the A.W.W.A. Specifications are specifically cited as permissible for current use as amended with the Emergency Alternate Provisions published below. Table 1 of Schedule 13 shows 342 combinations of thicknesses and sizes ($\frac{1}{8}$ in. to 48 in.) permissible under the Limitation Order. The A.W.W.A. standardized thicknesses and sizes are tabulated along with some twelve other standards of other organizations.

Thus, with the Emergency Alternate Provisions published below, A.W.W.A. Standards for steel pipe can be used during the National Emergency and currently according to the present Limitation Order L–211, and insofar as the use of steel for water pipe is permitted by WPB.

Tables Sec. A4–3 of A.W.W.A. 7A.4–1941–TR, which appeared, as then revised, on pages 493–98 of the April 1943 Journal, *are modified by reduction of the number of wall thicknesses from which the purchaser may choose in ordering* mill *pipe and* fabricated *pipe. These tables, thus modified, will be published in the October* Journal. *Assembled sheets listing the text modifications, published herewith, and the modified tables, to be published in October, will be provided as insert sheets for use with the Standard Specifications.*

Persons who need to refer to the emergency tables in the meantime may obtain copies of "L–211, Schedule 13" from the Conservation Div., War Pro-

duction Board, 1100 H St., N.W., Washington, D.C. The tables therein contained list the wall thicknesses permitted under all specifications for steel pipe which have been accepted by the WPB.

Emergency Alternate Provisions to A.W.W.A. 7A.3–1940

"A.W.W.A. 7A.3–1940—Standard Specifications for Electric Fusion Welded Steel Water Pipe of Sizes 30 Inches and Over" are amended for use during the National Emergency by the following Emergency Alternate Provisions, approved for the A.W. W.A. Board of Directors, July 24, 1943, by direction of the Board by:

MALCOLM PIRNIE, *Chairman*
Committee on Water Works Practice
REEVES NEWSOM, *Vice-Chairman*
Committee on Water Works Practice
HARRY E. JORDAN, *Secretary*
A.W.W.A.

Sec. 3–2.1(a), *revise to:* Steel Plate shall be selected by the manufacturer and shall conform to the requirements of one of the following specifications:

A.S.T.M. Designation A7, A10, or A78 Grade B.

Sec. 3–2.5, *revise to:* Longitudinal seams and all spiral seams shall be butt welded. Each pipe section shall have the minimum number of seams based upon the material available.

Sec. 3–2.6, *revise to:* Shop girth seams shall be butt welded. Each pipe section shall have the minimum number of seams based upon the material available.

Sec. 3–2.9 (*New*): Pipe thicknesses should be selected, not only with respect to the stresses to which the pipe will be subjected, but also with respect to the degree of corrosiveness of the soil and of the water to be carried, with due regard to the probable required life of the pipe and the cost of replacement. In cases where the water or ground, or both, have been known to be corrosive, due consideration should be given to the protection of steel water pipe, particularly that with thin walls. It is recommended that if coatings are used they comply with A.W. W.A. 7A.5–1940—Standard Specifications for Coal-Tar Enamel Protective Coatings for Steel Water Pipe of Sizes 30 Inches and Over.

Engineers who specify or contemplate specifying steel pipe to be produced according to these emergency alternate specifications should consider carefully the physical characteristics, allowable wall thicknesses and probable life of steel pipe which can be produced in conformance with them. If steel pipe of such physical characteristics and wall thicknesses is not judged to be applicable to the service conditions under which it is expected to be used, some other type of water pipe should be specified.

Emergency Alternate Provisions to A.W.W.A. 7A.4–1941–TR

"A.W.W.A. 7A.4–1941–TR—Tentative Revision of Standard Specifications for Steel Water Pipe of Sizes up to but Not Including 30 Inches" are amended for use during the National Emergency by the following Emergency Alternate Provisions, approved by the A.W.W.A. Board of Directors, June 19, 1943:

Sec. 4–1.1(2), under *Fabricated Pipe, add:*

Spiral-lap-joint in thicknesses 0.105

in. to 0.172 in. inclusive with the size limitations for these thicknesses as set forth in table Sec. A4–3.2 as amended herein.

Spiral-lock-seam-joint in thicknesses 0.105 in. to 0.172 in. inclusive with the size limitations for these thicknesses as set forth in table Sec. A4–3.2 as amended herein.

Sec. 4–2.2.2, *revise to:* Steel plate for *fabricated* pipe shall conform to the chemical requirements of one of the following specifications as selected by the manufacturer:

A.S.T.M. Designation A7, A10, A78 Grade A or B.

Sec. 4–2.2.3, *revise to:* Steel sheets or coils used in the *fabricated* pipe shall conform to the chemical requirements specified by A.S.T.M. Designation A245 of latest revision (Light Gage Structural Quality Flat Hot-Rolled Carbon Steel), or as otherwise specified by the purchaser.

Sec. 4–2.4.2, *revise to:* Steel plate used in *fabricated pipe* shall conform to the physical property requirements of one of the following specifications as selected by the manufacturer:

A.S.T.M. Designation A7, A10 or A78 Grade A or B.

Sec. 4–2.4.3, *revise to:* Steel sheets or coils used in *fabricated* pipe shall conform to the physical properties specified for Grades A, B or C in A.S.T.M. Designation A245 of latest revision (Light Gage Structural Quality Flat Hot-Rolled Carbon Steel), or as otherwise specified by the purchaser.

Sec. 4–3.2.1(a), *revise second sentence to read:* Each section of *fabricated* pipe shall have the minimum number of seams based on the material available.

Sec. A4–3.2, the following footnote is to appear on bottom of each page of the table:

NOTE: Pipe thicknesses should be selected, not only with respect to the stresses to which the pipe will be subjected, but also with respect to the degree of corrosiveness of the soil and of the water to be carried, with due regard to the probable required life of the pipe. In specifying steel pipe under these emergency alternate specifications, it is recommended that it be coated and lined in accordance with A.W.W.A. 7A.6–1940—Standard Specifications for Coal-Tar Enamel Protective Coatings for Steel Water Pipe of Sizes up to but Not Including 30 Inches in Diameter.

Engineers who specify or contemplate specifying steel pipe to be produced according to these emergency alternate specifications should consider carefully the physical characteristics, allowable wall thicknesses and probable life of steel pipe which can be produced in conformance with them. If steel pipe of such physical characteristics and wall thicknesses is not judged to be applicable to the service conditions under which it is expected to be used, some other type of water pipe should be specified.

War Production Board—Office of War Utilities

Administrative Letter to All Utilities—August 24, 1943

UTILITIES ORDER U-1-f

ATTACHED to this letter is Supplementary Utilities Order U–1–f which authorizes extensions of utilities service to industrial, commercial and domestic consumers, where the essential need is established and where there is no related construction or remodeling of the consumer's premises which would require an authorization from the War Production Board to begin the construction or remodeling.

This order enlarges the field in which utilities may build extensions without submitting an application for authority to proceed with each construction. For your information in operating under Order U–1–f, there follows a review of other Supplementary Orders in the U–1 series which also permit the construction of extensions:

Order U–1–a

Class of extensions: To serve establishments where the utilities services are contracted for by the armed forces.

An establishment of the armed forces may be served either under Order U–1–a or Order U–1–f.

Order U–1–b

Class of extensions: To serve cooking facilities (ranges).

The provisions of Order U–1–b are applicable to extensions of utilities facilities to serve ranges in areas not included in Schedule A of Order U–1–f. Since paragraph (b)(5) of Order U–1–f prohibits enlargements of service under the terms of the order, the provisions of Order U–1–b may be used in areas included in Schedule A of Order U–1–f where an enlargement of service (extension of a third wire) is needed to serve a range.

Order U–1–c

Class of extensions: To serve certain productive farm equipment.

Order U–1–d

Class of extensions: To serve buildings, the renovation or construction of which requires approval under Conservation Order L–41. As an example: if construction or renovation of a dwelling will cost more than $200 for materials, labor and applicable builder's charges, under Order L–41, the builder or person undertaking the renovation must get approval from the War Production Board to begin construction. If, in addition to the construction or renovation of the dwelling, extensions of utilities services are required, the latter may be constructed under the provisions of Order U–1–d, if the customer's construction is authorized under L–41. If the cost of the construction or renovation of the

dwelling will be less than $200 for material and labor, however, no approval is required under Order L-41 if the utility extension is made under the provisions of Order U-1-f and, in such cases, the construction of utilities facilities is governed by Order U-1-f.

Order U-1-e

Class of extensions: Water service to Victory Gardens.

Service to Domestic Consumers Under Order U-1-f

In order to qualify under U-1-f for an extension of electric, gas or central steam heat services, the consumer's premises must be located in one of the areas described in Schedule A of the order. These areas are those within which the National Housing Agency has determined that extensions of utilities services will be of substantial benefit in reducing a shortage of adequate housing facilities. This list may be changed from time to time as housing shortages are alleviated or as new critical housing shortages develop. Such changes in Schedule A will be made only in accordance with recommendations of the National Housing Agency.

Extensions of water services are not restricted to the localities defined in Schedule A and may be made in any locality so long as the other restrictions of the order are not exceeded. This broader authorization for water extensions is made for the reason that there is no substitute for an adequate water supply, while there are, in most instances, effectual substitutes for electricity, gas and central steam heat.

Buildings not used as "year-round" dwellings (such as summer cottages and houses) are not considered to be "buildings used exclusively for dwelling purposes," within the meaning of this order and extensions of service thereto are not permitted under this order.

Utilities retain the usual right to appeal from the restrictions of Utilities Order U-1-f. Such appeals should be submitted to the Office of War Utilities, War Production Board, Washington, D.C., on Form WPB-2774 [see p. 977, July JOURNAL]. Consideration will be given to such applications in the case of extensions to domestic consumers only if the following conditions obtain and are shown in the application:

1. The dwelling will be used as a lodging by a member of the armed forces, by a physician or a registered nurse, by an employee of an Army or Navy establishment or by an employee of an industry producing one of the products or rendering one of the services listed in Schedules I and II of CMP Regulation 5, and such dwelling is within ten miles of the person's place of employment, measured in a straight line.
2. The extension of service will help remedy a shortage of housing facilities in the locality.
3. The Utilities Construction Standards applicable to domestic consumers (Schedule B) are not exceeded.

Service to Industrial and Commercial Consumers Under U-1-f

For your convenience, copies of Schedules I and II of CMP Regulation 5, as amended to May 14, 1943, are attached to this administrative letter. [These schedules are not reproduced here; they should be obtained from the nearest office of the War Production Board.]

In the case of a commercial consumer, the term "Engaged in the manufacture of a product or in the conduct

of a business or activity listed in Schedules I or II of CMP Regulation 5" means that the consumer is directly connected with the industry or activity listed. For example, offices occupied by employees directly engaged in the management or administration of one of the industries or activities listed would be eligible for service, as would be warehouses for storage of materials used by a specific industry or activity so listed. Offices or establishments not engaged in rendering direct service to such industries or activities, for example, stores, insurance offices, restaurants, places of amusement, etc., are not eligible for extensions of service under the order. Extensions of service for street lighting and the installation of fire hydrants may not be made under the provisions of this order.

Applications to serve commercial and industrial establishments not covered by U-1-f should be made on Form WPB-2774 and addressed to the Office of War Utilities, War Production Board, Washington, D.C. Such applications will be given consideration only if the extension is for a war production plant, a military establishment or an essential community service, or is necessary for the public health or safety, and if the minimum use of critical material is planned.

Utilities Construction Standards (Schedule B)

The amounts and kinds of material that may be used in any one extension are specified in Schedule B. It should be noted that these amounts may be used for "each domestic, industrial, or commercial consumer as defined in paragraph (a) of this order." This means that a utility proposing to serve a building containing several apartments or several commercial establishments, or proposing to serve a domestic consumer having a group of buildings on his premises, would be eligible to use only that amount of material permitted by the Utilities Construction Standards (Schedule B) for the construction of service to one consumer.

These standards are designed to provide flexibility in the use of material for utilities extensions under the order and to conserve scarce materials and equipment by encouraging the substitution of less scarce materials. Thus, in the case of electric extensions, if the installation of a separate transformer can be avoided by an additional run of secondary, an additional 25 lb. of non-ferrous metal may be used in the extension. If an extension will include both primary and secondary lines, the permissible 20 lb. of non-ferrous metal in the secondary part of the extension must be reduced by 1 lb. for each 90 conductor feet of the conductor used in the primary. For example, if the extension of primary would be 270 ft. long (540 conductor feet), the amount of non-ferrous metal permitted for the secondary extension would be reduced to 14 lb.

Steel conductor may be used for primary extensions and may be purchased for that purpose from any supplier, including a warehouse or manufacturer. The composite types of conductor (for example "copperweld-copper," "Amerductor," "ACSR") may be used in primary extensions if the conductivity is equivalent to or less than No. 6 copper conductor, and only if such composite conductor is available in the producer's excess stock or is purchased from the excess stock of another producer.

In the case of gas, central steam heat and water extensions, the use of cast-iron, lead or non-metallic pipe instead of steel pipe is encouraged. If

the distribution pressure is less than 100 psi., no steel pipe may be used in the extension unless such pipe is available in the producer's excess inventory or can be purchased from the excess inventory of another producer.

In the case of extensions where the operating pressure exceeds 100 psi., the steel pipe for the extension may be purchased from any supplier if it is not available in excess inventory.

In the case of gas extensions, the utility has the choice of using a combination of steel and cast-iron pipe. For example, the entire extension might be of either cast-iron pipe or of steel pipe within the weight limits permitted, or if a combination of steel and cast-iron were used in cases of an extension of service to a domestic consumer and the steel pipe used in the service weighs 150 lb., then the permissible weight of cast-iron pipe that may be used would be reduced from 1200 lb. to 900 lb. (1200 minus 2×150). A similar relationship has been created between steel pipe and cast-iron pipe for water extensions. However, in the case of water extensions, there is an additional choice of lead or lead-alloy pipe. For example, if a water utility runs a service to a domestic consumer using 400 lb. of lead or lead-alloy pipe, the amount of cast-iron pipe that may be used in the extension is reduced from 1200 lb. to 800 lb. (that is, the cast-iron pipe permitted is reduced by the weight of the lead or lead-alloy pipe used). Conservation Order M-9-c-4 of the War Production Board prohibits the use of copper or copper-base-alloy pipe in the construction of new water services.

Non-metallic pipe, such as cement-asbestos and other types of pipe containing no metal, may be used in extension of service on the same basis (length for length) as cast-iron pipe. For example, assume that 150 lb. of steel pipe and 60 ft. of main is required for an extension to a domestic consumer. The utility would have the choice of using 60 ft. of non-metallic pipe or 60 ft. of 4-in. cast-iron pipe (weight approximately 900 lb.).

(signed)
J. A. Krug, *Director*
Office of War Utilities

Editor's Note: Order U-1-f, reproduced on the following pages, in the form issued by the Office of War Utilities, was not discussed with representatives of the public water supply industry. Exceptions to certain of its terms have been filed with the Administrator of the order.—*Harry E. Jordan.*

TITLE—NATIONAL DEFENSE

Chapter IX—War Production Board

Subchapter C—Director, Office of War Utilities

Part 4500—Electric, Gas, Water and Steam Utilities—Materials

SUPPLEMENTARY UTILITIES ORDER U-1-f

§4500.7 *Supplementary Utilities Order U-1-f*—(a) *Definitions:* For the purposes of this supplementary order:

(1) "Domestic consumer" means a prospective consumer who is requesting an extension of service to a building used exclusively for dwelling purposes.

(2) "Industrial consumer" means a prospective consumer who is requesting an extension of service to a building used in whole or in part for the manufacture, processing or assembly of products or materials.

(3) "Commercial consumer" means a prospective consumer not classified in this order as "domestic" or "industrial."

(b) *Permission to build certain extensions:* Notwithstanding the provisions of paragraph (h)(1) of Utilities Order U-1, facilities other than temporary facilities may be built by producers to furnish electric, gas, water and central steam heating service, provided that all of the following conditions are satisfied:

(1) Where construction or remodeling by the consumer is involved, no specific direction, order, certificate or other authorization for construction has been issued by the War Production Board to authorize such construction or remodeling. If such authorization has been issued, the construction of utility facilities is governed by Supplementary Utilities Order U-1-d.

(2) In the case of gas and electric facilities to serve domestic consumers, the dwelling to be served is in a locality listed in Schedule A of this order.

(3) In the case of facilities to serve industrial or commercial consumers:

(i) The cost of utilities facilities, including any part thereof built by or for the consumer does not exceed $1500 in the case of underground construction or $500 in the case of other construction, and

(ii) The consumer is engaged in the manufacture of a product or in the conduct of a business or activity listed in Schedules I or II of CMP Regulation 5, as amended.

(4) Utility facilities can be built within the limits of the Utilities Construction Standards, shown in Schedule B of this order.

(5) The connection does not duplicate an adequate service already installed, or constitute a standby service, or an enlargement of a service already installed.

(6) No other producer can render the same service with less use of critical material.

(c) This order does not constitute a release, in the case of gas producers or consumers, from the provisions of Limitation Orders L-31 or L-174.

Issued this 24th day of August 1943.

War Production Board
By J. Joseph Whelan
Recording Secretary

Schedule A

Localities in which extensions of utilities services are permissible under the provisions of this Supplementary Utilities Order U–1–f.

[*This does not apply to water service extensions—only to electric and gas service lines (see Sec. (b)(2) of the order.—Ed.*]

In the case of localities listed below where the United States Department of Commerce, Bureau of the Census, has established a "Metropolitan Area," extension of service pursuant to the provisions of this order, U–1–f, can be made anywhere within such area; localities in which the Bureau of the Census has designated a Metropolitan Area are indicated in the following list by an asterisk. In the remainder of the localities listed below, where no Metropolitan Area has been established by the Bureau of the Census, extensions pursuant to the provisions of this supplementary order, U–1–f, may be made anywhere within the city or corporate limits of the locality and at a distance not to exceed ten miles in a straight line from such city or corporate limits.

Locality

Alabama:
*Birmingham
Huntsville
*Mobile
Muscle Shoals

Arizona:
*Phoenix
Tucson
Yuma

Arkansas:
Blytheville
Pine Bluff
Newport
Stuttgart

California:
*Los Angeles
Oxnard
San Bernardino-Riverside
*San Diego
*San Francisco
*San Jose
*Stockton

Colorado:
Colorado Springs
*Denver
Pando
*Pueblo

Connecticut:
*Bridgeport
Bristol
*Hartford
Meriden
New Britain
*New Haven
New London
Stamford
*Waterbury

Delaware:
*Wilmington

Dist. of Columbia:
*Washington

Florida:
*Jacksonville
Key West
Panama City
Pensacola
*Tampa

Georgia:
*Atlanta-Marietta
Brunswick
*Macon-Wellston
*Savannah

Idaho:
Bayview-Coeur d'Alene
Mountain Home
Pocatello

Illinois:
*Chicago
*Decatur-Springfield
DeKalb
*Rockford

Indiana:
Anderson
Connersville
*Evansville
*Fort Wayne
Gary-Hammond
Indianapolis
Richmond-Newcastle
*South Bend
Terre Haute

Iowa:
*Des Moines

Kansas:
Eudora
*Kansas City (*see* Kansas City, Mo.)
Winfield

Kentucky:
Fort Knox
*Louisville
Morganfield
Richmond

Louisiana:
Alexandria
Baton Rouge
*New Orleans

Maine:
Bath-Brunswick
Houlton
*Portland
Presque Isle

Maryland:
Aberdeen
*Baltimore
Edgewood
Elkton
St. Marys County

Massachusetts:
Camp Edwards
Greenfield
Lynn
Quincy-Hingham
*Worcester

Michigan:
Adrian
Battle Creek
Benton Harbor
*Detroit
*Flint
Jackson
Muskegon
*Saginaw-Bay City
Midland

Minnesota:
*Duluth

Mississippi:
Biloxi
Grenada
Gulfport
Pascagoula

Missouri:
*Kansas City
Warrenton

Montana:
Butte
Columbus
Great Falls

Nebraska:
Alliance
Grand Island
Hastings
Sidney
Wahoo

Nevada:
Las Vegas

New Hampshire:
Claremont
Portsmouth
Somersworth

New Jersey:
Camden
*North Eastern New Jersey Area
Red Bank-Long Branch
*Trenton

New York:
*Buffalo-Niagara Falls
Elmira
*Schenectady
*Syracuse
*Utica-Rome

North Carolina:
Burlington
Goldsboro
Laurinburg
New Bern
Wilmington

Ohio:
*Cincinnati
*Cleveland
*Dayton
*Hamilton-Middletown
Lima
Mansfield
Medina
Newark
Port Clinton
Sidney-Piqua-Troy
*Springfield
*Toledo

Oklahoma:
McAlester
*Oklahoma City
*Tulsa

Oregon:
Astoria
Bend
Corvallis
*Portland-Vancouver

Pennsylvania:
*Allentown-Bethlehem
Beaver County
Chambersburg
Charleroi
Coatesville
*Erie
*Harrisburg
Bristol
*Pittsburgh
*Pottstown-Reading
Chester

Rhode Island:
Newport
*Providence
Quonset Point

South Carolina:
*Charleston

South Dakota:
Provo-Edgemont
Sioux Falls

Tennessee:
Bristol-Kingsport
*Memphis

Texas:
*Amarillo
*Beaumont-Orange-Port Arthur
*Corpus Christi
*Dallas
*Fort Worth
*Galveston-Texas City
*Houston
Texarkana

Utah:
Drager
Ogden
Provo
*Salt Lake City
Tooele
Wendover

Vermont:
Springfield
Windsor

Virginia:
*Newport News
*Norfolk-Portsmouth

Washington:
Bremerton
Everett
*Seattle-Renton
*Spokane
*Tacoma

Wisconsin:
*Madison-Merrimac
*Racine-Kenosha
*Superior (*see* Duluth, Minn.)

Wyoming:
Casper
Cheyenne
Laramie
Rawlins
Rock Springs

Schedule B

Utilities Construction Standards

The material used in extensions permitted by Supplementary Utilities Order U-1-f must conform to this Schedule B and must not exceed, within the dollar value limits of paragraph (b) (3) (i) of this order, the quantities shown below for each domestic, industrial, or commercial consumer as defined in paragraph (a) of this order.

A. Permitted Types of Conductor and Pipe

I. *Electric conductor for primary:*

a. Steel, or

b. Any other type of conductor not consisting exclusively of copper, which is available in the producer's inventory in excess of a practical working minimum, or in such excess inventory of another producer, and having a conductivity equal to or less than No. 6 AWG copper conductor.

II. *Electric conductor for secondary:* No limitation except for domestic extensions. In the case of domestic: any type of conductor having a conductivity equivalent to or less than that of No. 6 AWG copper conductor.

III. *Pipe:*

a. Cast iron, for working pressures of 100 psi. or less.

b. Steel, for working pressures of over 100 psi., or for working pressures of 100 psi. or less provided it is available in the producer's excess inventory or in the excess inventory of another producer.

c. Non-metallic.

B. Permitted Quantities of Conductor and Pipe, Other Than Non-metallic

I. *Domestic consumers*—a. *For electric extensions:*

(1) For primary lines, up to 900 conductor feet of any conductor permitted by Section I above.

(2) For secondary lines and service drops, up to 20 lb. of non-ferrous metal in conductor, less 1 lb. of non-ferrous metal for each 90 conductor feet or fraction thereof of conductor used in the primary extension. *Provided, however,* That up to 45 lb. of copper in conductor may be used in the extension of secondary and service drops, if the service may be rendered from a transformer already installed and in service.

b. *For gas or central steam heating extensions:*

(1) Up to 170 lb. of steel pipe or 1200 lb. of cast-iron pipe.

(2) A combination involving not more than 170 lb. of steel pipe and not more than 1200 lb. of cast-iron pipe less twice the weight of any steel pipe used.

c. *For water extensions:*

(1) Up to 170 lb. of steel pipe, or 1200 lb. of cast-iron pipe, or 600 lb. of lead or lead-alloy pipe, or

(2) Either of the following combinations:

(a) Not more than 170 lb. of steel pipe and not more than 1200 lb. of cast-iron pipe less twice the weight of any steel pipe used.

(b) Not more than 600 lb. of lead or lead-alloy pipe and not more than 1200 lb. of cast-iron pipe less the weight of any lead or lead alloy pipe used.

II. *Industrial consumers*—The smallest size or quantities of equipment, conductor or pipe required to furnish electricity, gas, water or central steam heat at minimum service standards.

III. *Commercial consumers*—a. *For electric extensions:*

(1) For primary lines, up to 900 conductor feet of any conductor permitted by Section I above.

(2) For secondary lines and service drops, up to 40 lb. of non-ferrous metal in conductor, less 1 lb. of non-ferrous metal for each 90 conductor feet or fraction thereof of conductor used in the primary extension; *Provided however,* That up to 65 lb. of copper in conductor may be used in the extension of secondary and service drops, if the service may be rendered from a transformer already installed and in service.

b. *For gas or central steam heat extensions:*

(1) Up to 250 lb. of steel pipe, or 1800 lb. of cast-iron pipe, or

(2) A combination of not more than 250 lb. of steel pipe and not more than 1800 lb. of cast-iron pipe less twice the weight of any steel pipe used.

c. *For water extensions:*

(1) Up to 250 lb. of steel pipe, or 1800 lb. of cast-iron pipe, or 1000 lb. of lead or lead-alloy pipe, or

(2) Either of the following combinations:

(a) Not more than 250 lb. of steel pipe, and not more than 1800 lb. of cast-iron pipe less twice the weight of any steel pipe used, or

(b) Not more than 1000 lb. of lead or lead-alloy pipe, and 1800 lb. of cast-iron pipe less the weight of any lead pipe used.

C. Permitted Quantities of Non-metallic Pipe

Non-metallic pipe of a length not greater than that length which would be installed if cast-iron pipe were used in accordance with the quantities in the above standards.

Limitation Order L-39 Revised

LIMITATION Order L–39 which covers fire protective, signal and alarm equipment was extensively revised as of August 23, 1943. The order covers sprinkler systems, couplings, playpipes and allied fittings, fire hose, fire hydrants, fire pumps, hose dryers, hose racks, indicator posts, lightning protection systems, piped extinguishing systems, portable fire extinguishers, including back-pack types, foam generators, stirrup pumps, water spray nozzles and all other fire protective equipment for preventing or extinguishing fires, except self-propelled motorized fire apparatus and auxiliary units including trailer, skid-front mounted and portable apparatus. It also includes fire, police and protective alarm and signal systems, including central station, proprietary, auxiliary and automatic fire alarms; watchmen's time recording, burglar, bank vault, hold-up and intrusion systems; and all other instruments and devices to detect, signal or warn against fire or other casualty, except air raid warning devices.

This order primarily relates to industrial plant fire protection, as is evidenced by its detailed coverage of fire sprinkler systems, signal and alarm equipment, fire hose, etc. The restrictions upon material used in the manufacture of fire hydrants contained in Appendix A, Subsection (5)(xvii) are unchanged from the restrictions which were published in the copy of the order in the March 1943 JOURNAL (p. 414).

Since the content of the order is not of first line importance to public water supply administrators, it will not be repeated in the JOURNAL. Copies may be obtained from any office of the War Production Board.

War Production Board—Office of War Utilities

Letter to All Water Utilities—July 28, 1943

At a meeting on July 6, the War Production Board decided to initiate and sponsor a broad conservation program for voluntary conservation of coal, petroleum products, transportation, gas, electricity, water and communications to be undertaken by the government in co-operation with the industries concerned. Maximum war production requires the greatest possible conservation of manpower, transportation, fuel, equipment and critical materials, such as copper, steel and many others. The Board has requested the Office of Defense Transportation, the Petroleum Administration for War, the Solid Fuels Administrator for War and the Office of War Utilities to develop detailed programs with the industries for which they are responsible and, through these industries, to enlist the co-operation of all citizens in this necessary conservation program.

On July 28, the Office of War Utilities, in consultation with the Committee on Wartime Water Works Practice of the American Water Works Association, developed a comprehensive program to achieve the objectives of the War Production Board within the water industry. Enclosed is a copy of the report covering this program.

You are urgently requested to take the necessary steps to develop the program within your territory so that it may be made effective, as an important part of the overall conservation program, for the entire country in the early part of September.

If every water utility co-operates to the fullest extent in the program that has been outlined, its complete success will be assured. I am confident that we will have that degree of co-operation from the entire water industry.

J. A. Krug, *Director*
Office of War Utilities

Report on Voluntary Conservation Program for Water Utility Industry

The American Water Works Association's Committee on Wartime Water Works Practice was called together by J. A. Krug on July 28, 1943, to formulate a plan for co-operation of public water supply operators with the broad conservation program which was first publicized by an OWI release dated July 22, 1943. Portions of this statement merit repetition here.

"Secretary of the Interior Harold L. Ickes, Defense Transportation Director Joseph B. Eastman and War Production Board Chairman Donald M. Nelson in a joint statement asked the coal, petroleum, electric, natural and manufactured gas, water supply, communications and transportation industries to

formulate plans for an intensive voluntary campaign to get under way late this summer.

"These savings and the countless others that will result from a broad conservation campaign may appear small in the average household or the average industrial or commercial plant. Multiplied by millions of home and thousands of factories and stores, however, they are tremendous. The saving of a single ton of coal next winter by one householder will not win the war. But, if 18 million householders do it their combined effort will go a long way toward winning the war. That same thing applied with equal or even greater force to each of the other industries represented.

"We have, therefore, called upon the coal, petroleum, electric, natural and manufactured gas, water, communications and transportation industries to join with us in a broad conservation campaign to accomplish these results. The campaign will be voluntary. Co-operation of these industries in asking the public to use their services only as absolutely necessary represents a real sacrifice by them. We ask the American public to appreciate that sacrifice and to give them and the war effort enthusiastic and unstinting co-operation as this campaign develops."

It is evident that both the co-operation developed and the results achieved on the part of water works executives depend largely upon the quality of the fundamental promotion that the above-listed governmental agencies provide.

It is understandable that the receptivity of the American public to campaigns or drives does not have the spontaneity that it had two or three years ago. All of the meritorious wartime campaigns—bonds, civilian defense, salvage—repeated as they have been in many forms, have left John P. Citizen less able to spring to "attention" than he once was. To overcome this, each succeeding activity must have a higher quality of promotion and greater force in its execution.

So whatever the water, coal, petroleum, transportation, gas, electric power or communications industries are able to do in their respective fields to promote reasonable conservation of their services will depend, for the degree of its success, upon the quality of the general and fundamental support given to the overall conservation program by the governmental agencies who have initiated it.

1. Objective

Water is a basic war material. It is essential to the war effort and to the civilian economy which supports the war effort. Without water, planes, guns, tanks, ships and all the things the military agencies need, cannot be produced. The public water supply industry has accepted the responsibility of making this war material—water—available to all those who need it. It must be used wisely.

The industry thus accepts its responsibility to campaign for the elimination of water waste. Water wasted has required for its production just as much material and manpower as water that is consumed for a useful purpose. Waste, whether it be water or fuel or power or manpower, helps only the enemies of America.

Our primary objectives are to make public water supply work to its maximum value in the war effort and to prevent its waste by anyone. To attain these objectives we set for ourselves the elimination of those combinations of use and waste of water which build up excessive seasonal peaks in demand, as well as the further task of developing for our industry and its customers the elimination of year-round waste—either by domestic consumers or by the largest industry's non-useful draft upon the supply.

In the attainment of these objectives we do not propose to curtail the necessary use of water either by industry or by the general public.

2. Nature of a Water Conservation Program

A program for conservation of water logically divides itself into two lines of endeavor. One is a series of steps in the interest of waste reduction at all seasons and the other is a series of steps in the interest of reducing peak loads.

Year-round conservation extends all the way from stopping the wasted drops second by second at the more than one hundred and fifty million water fixtures to the elimination of major waste in the distribution system and the reduction of low-value use of water in industry. It is a continuing program of customer education and stimulation to action to the end that, just as fats and scrap are saved, so also, water, like power, gas, coal and transportation will be used only as it renders necessary service.

In the water supply field a program of seasonal conservation is of utmost importance. Due to the growth of commercial and industrial demand for water supply and due likewise to the fact that many war industries operate around the clock and give few hours relief from their demands upon water supplies, the seasonal loads, such as lawn sprinkling and irrigation, superimpose an added demand of such magnitude as either to require additional equipment or to cause a failure of the water supply to meet all the community needs.

Such a calamity can be averted by an intelligently conceived and executed water conservation program.

3. General Plan of Campaign

(a) It is understood that all industry groups (power, gas, coal, oil, communications, transportation and water) participating in this national campaign to promote conservation of service and service-consumed materials will have the guidance of the War Production Board expressed through both a small inter-industry representative group covering the entire field as well as through an intra-industry group for each service or commodity participating.

(b) The general conservation program is scheduled to open about September 15. At that time public statements will be made by federal officials in order to give every industry which participates, as well as every consumer of service, a background of support for the work which must be done in the various communities over the country.

(c) It appears that the major emphasis in a water conservation program should be directed toward the approximately 1100 cities having over 10,000 population. These cities have a total population approximating 63 million persons or almost 75% of the citizens of the United States who have public water supply available to them. Nothing but the limitations of manpower and resources for the central guidance of the campaign leads to this limited scope. No community is too small to save water and every such community, upon the asking, will receive all the guidance and counsel that can be given to it.

(d) For the industry as a whole it appears proper for the American Water Works Association, with the co-operation of the New England Water Works Association to give the program active direction. In the end, each water utility must bring the program home to its own customers—making use of the counsel of the War Production Board and the Office of War Information, the central guidance of the American Water Works Association and the regional co-operation of water works associa-

tion sections, state water co-ordinators, conferences of mayors, municipal leagues and all the other groups which have the ability to serve in this direction.

(e) Water users must be fully advised that the campaign to promote water conservation (fundamentally meritorious as it is) does not, at this time, stand by itself alone. It is a part of a broad and nationally sponsored campaign initiated in the public's wartime interest. This campaign looks not alone to the conservation of water supply but is based upon the nation's need to make the best possible use of all materials and services—in particular, water, gas, electricity, coal, oil, transportation and communications, as well as the manpower required to produce these materials and services.

(f) It is understood that in a community where water supply is fully adequate and where the savings which could be effected by such a campaign would be productive only to a minor degree, active participation in the campaign is not indicated.

(g) At either the national, regional or local levels, the related engineering and health associations and authorities should be advised fully in all details related to the need for reasoned use of water supply as well as the control and elimination of waste. There is no intention to curtail any use of water which is essentially related to public health or safety.

(h) In every city where the conservation program is undertaken the various utility, fuel and service executives are definitely expected to consult with each other and to acquaint each other as fully as possible with the nature of the use and waste problems of the other. Publicity programs of each should be reviewed with the others to the end that the fullest accord and co-ordination in presentation of facts to the public is developed.

4. Conservation Control Measures

The measures which promise to bring about the desired elimination of waste of water may be listed as follows (not necessarily in the order of their importance):

(a) *Premise inspections by the customer:* Detection of waste in the household. Repair of leaking faucets and toilets.

(b) *Distribution system leakage studies:* Detection and repair of leaks in the mains and service lines in the street.

(c) *Hydrant inspections by firemen and policemen:* Control of use of hydrants against use for any purpose other than fire fighting.

(d) *Advice concerning proper lawn watering:* Use of bulletins, etc., to show that frequent and heavy watering of lawns will not improve the lawn.

(e) *Consulting engineering service:* Advice concerning better methods of operation, involving ingenuity and the experience of others.

(f) *Contact with industry, especially that engaged in war work:* This category of customers, operating on the war-boom basis, is most likely to be wasting large amounts of water or using it in such fashion as to obtain little service from it. Here re-use is often possible.

(g) Seasonal or peak load conservation measures. Among these are:

(1) Promotion of the most effective use of water in industry—with emphasis upon re-use of water whenever production and sanitation conditions permit

(2) Staggering or limitation of lawn sprinkling

(3) Reduction of air-conditioning uses of water

(4) Definite control of irrigation uses

(5) Drastic reduction of sewer flushing

(6) Reduction of street washing

(7) Control of public or semi-public drinking fountains, swimming pools, etc.

Many of these steps require complete co-operation from other city departments and/or approval by the public service commission.

(h) *Metering:* The metering of all consumers has been and is recognized as being one of the principal measures, if not the most important one, which is effective in the reduction of water waste. Due, however, to the shortage in materials now needed for direct munitions of war and the limitations orders of the War Production Board on these materials, a normal metering program must be curtailed until such time as these scarce materials can be spared. It is taken for granted, however, that in special cases, involving immediate metering of large as well as small services as a water conservation measure, the War Production Board will recognize the necessity of and grant permission for such installations.

5. Publicity Media

The media for publicity in order of their apparent value in water conservation are:

(a) Direct to consumer material, such as cards, folders, blotter, stickers on bills and personal contact by employees

(b) Newspaper advertising

(c) Radio appeals

(d) Posters in utility offices, public transportation vehicles, etc.

(e) Addresses before luncheon clubs, labor groups, women's clubs, civic clubs, etc.

(f) Contacts with municipal and state authorities to develop official support of the program—to reduce public and institutional waste of water

(g) Contacts with school authorities to develop "junior-citizen" interest in and support of waste control.

6. Publicity Manual

In order to provide water utilities with suggestive material for their use in local campaigns, a "guidebook" or "packet" will be developed for controlled distribution. It is contemplated that this booklet will contain specimens of advertising copy, posters, consumer cards, car cards, radio addresses, luncheon and civic club addresses, etc., as well as mayor's proclamations, city council ordinances, etc., which have been or may be used to implement conservation campaigns.

7. Promotion of Regional Activity

It is contemplated that forthcoming regional conferences of water works men will set up as a part of the schedule of subjects for discussion the entire conservation program and the means to be taken to energize it in their respective areas. In other words, it is assumed that in such conferences as the Maine Utilities Association, the New England Water Works Association, the Pennsylvania Water Works Association, the Water and Sewage Works Conferences of Illinois, North Dakota, South Dakota, Missouri *and other states,* the inter-county meetings of water works men in the State of Texas, as well as in the various section meetings of the American Water Works Association, full discussion of the entire conservation program will

be had and special organization set up to stimulate local activity.

A program of this character requires for its success that whenever and wherever water works men gather in conference they consider and put into effect every possible step that can be taken to make the water-consuming public conscious of its part in the water saving campaign.

8. Reports of Results Attained

The War Production Board and, in particular, the Office of War Utilities is in a position to outline the reporting procedure to be used by the utilities participating in the program. But, in outlining the form of reports and stipulating the frequency with which they should be filed, it is assumed that the OWU will not overlook the present attitude of civilians, which is not enthusiastic when additional reports are suggested. Neither is it assumed that the OWU will ask for reports beyond its own capacity of analysis and subsequent release.

From the viewpoint of the operating water utility it appears that there would exist a desire to record some data regarding the following results of the conservation program:

(a) Economies in fuel
(b) Economies in chemicals for water treatment
(c) Economies in miscellaneous materials and equipment
(d) Economies in use of manpower
(e) Deferred capital expenditures
(f) Improved service to customers
(g) Customer co-operation accorded the program

Generally the satisfaction over having achieved the desired results can be expected to lead the utility executive to record the results.

Respectfully submitted,
Task Committee of the Water Utility Industry

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